Water and Energy

Conservation Alternatives for the North

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WATER AND ENERGY CONSERVATION ALTERNATIVES FOR THE NORTH

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ABSTRACT

Although the north is generally endowed with abundant water, there are areas and communities that do not have sufficient year round potable water supplies. Even where water is readily available, the procurement and distribution of adequate potable water and the safe collection and disposal of wastewater is difficult and expensive. The application and acceptance of appropriate and cost-effective water conservation methods and technology can improve the level of service and sanitation and the economics of providing water and sewage services in northern communities.

This report reviews water use characteristics, pricing policies, plumbing codes, public acceptance, water conservation experiences and the methods and technology to reduce water demand and the concomitant energy requirements. Various administrative alternatives and water conservation technology for toilets, bathing, laundry, kitchen and households are scrutinized with respect to appropriateness, public acceptance and cost-effectiveness. An economic analysis methodology is formulated and water conservation strategies for both trucked and piped utility systems are presented.

Households with full conventional plumbing that are serviced by piped water and sewer systems typically use 225 L/person·d but water demand can exceed 2500 L/person·d where bleeding is used to prevent freezing. The major benefits of water conservation are usually the reduction in household hot water heating requirements and utility system operating costs, particularly where preheating or treatment of water is necessary. To economically reduce water demand, simple dual flush or dam attachments for conventional toilets, low flow shower heads and flow control aerators for faucets are recommended. In some cases, low water use European toilets, front load washing machines, mixing faucets, insulated hot water lines and a pressure reducer are attractive. The installation of these devices would reduce water demand by 28% to 55% and the present value of the savings over conventional plumbing would be $450. to $5,200. per household depending on the devices used, bathing habits and the cost for water and energy.

Northern households with full conventional plumbing that are serviced by trucked water delivery and sewage pumpout typically use 95 L/person·d. Because of the high unit cost of water for trucked systems, existing conventional toilets should be replaced with toilets that use 3 L or less per flush. Low flow shower heads and flow control aerators are very economical and most househods will find it economical to install a front load washing machine. Other attractive alternatives include temperature control valves, a hand-held shower unit, mixing faucets, insulated hot water lines and a circulating or return hot water system. The recommendations outlined would reduce water demand by 50% to 74%. It is estimated that by installing cost-effective water conservation plumbing fixtures, the household water requirements could be reduced to 50 L/person·d with little conscious effort on the part of the homeowners to conserve water. The present value of the savings over conventional plumbing would be $2,000. to $6,000. per household depending on the cost of water and whether this was a new installation or a retrofit.

For communities with a limited supply of water, trucked systems are preferred and very low water use fixtures such as recirculating toilet, self-closing hand-held shower unit and spray faucets are recommended. It is estimated that adequate sanitation can be achieved with only 21 L/person·d. Even in these critical situations, household reuse of water is not economically or socially attractive compared to water conservation.

A water conservation demonstration project to monitor retrofit and new installations for both piped and trucked systems is recommended.

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1 INTRODUCTION

1.1 General

The availability of water in sufficient quantity and acceptable quality is basic to human life and a utility system which will provide adequate water supplies and the safe collection of waste is fundamental to the health and growth of communities. Although Canada, and in particular northern Canada, is generally endowed with abundant water, there are some areas and communities that do not have sufficient year round potable water supplies. Even where water is readily available, the procurement and distribution of water and the collection and disposal of sewage is difficult and expensive. Given that the cost to provide water and sewage service is much higher in the north than in southern Canada, it follows that the benefits of water conservation would be greater in the north. Therefore, the appropriate methods and cost-effective technology to implement water conservation will be different and must be ascertained.

The impetus for this study was accrued from the on-going effort of the Government of the Northwest Territories to achieve a high degree of cost-effectiveness in the provision of water and sanitation services. The purpose of this report is to review water requirements and the methods and technology to reduce water demand and the concomitant energy requirements. The report reviews the literature on water use characteristics pricing policies, public acceptance and water conservation experiences. Methods and alternative technology are presented and evaluated. The technology is described and summarized in tables and a list of suppliers is provided in the Appendices. An economic analysis methodology is formulated and the procedure and results for typical conditions are provided. While the report is oriented towards residential housing in the north, water conservation is important for other conditions and locations. The report is written so that anyone can review the alternatives and select the most appropriate and cost-effective strategy for their particular conditions.

1.2 Why Conserve Water

Recent water shortages in many parts of the world and the "energy crisis" have publicized the need for reducing demand. Less dramatic but perhaps more significant in the long run is the increased public concern for reducing waste and conserving our natural resources. Also, in a strictly economic analysis, water conservation and the concomitant energy savings make "cents".

The desire for water conservation may be philosophical and/or economical. In this report the emphasis and the analysis of water conservation technology is based upon the long term cost-effectiveness and not a response to periodic crisis situations nor a philosophical/ environmental approach. The benefits will vary with the local conditions and the utility system and may be accrued by the consumers, utility operators, agencies supplying subsidies and by the nation.

Water conservation will reduce the total and the peak demands; therefore, the necessary capacity of water and sewage facilities will be less. Reducing demand may extend the life of existing facilities, or alternatively, the existing facilities may be used to service more consumers. Capital expenditures for expansion may be deferred or obviated and reduced capacity requirements will result in a lower cost for new facilities. Variable operating costs such as pumping, heating, chemicals and labour for utility systems will be reduced. In some cases reduced demand may improve the reliability of utility systems and water conservation may make alternative utility systems such as trucked systems viable and more economical compared to piped systems.

The consumer will benefit from reduced utility system capital and operating costs through lower bills, even though the unit price may be higher in order to return the necessary revenue to the utility operators. The consumer will also benefit from reduced hot water consumption through lower energy bills and the convenience of seemingly increased capacity from existing hot water heating systems. Water conservation in existing buildings served by trucked systems would reduce the frequency of servicing. The buildings would be more independent and, therefore, less influenced by disruptions in service and less prone to running out of water or overflowing sewage holding tanks.

1.3 Northern Utility Systems

In order to appreciate the application and benefits of water and concomitant energy conservation in the north, it is worthwhile to consider the conditions and characterisitcs which influence utility systems. There are three distinct geographical regions of the north; the areas with permafrost, those without, and the area of sporadic or discontinuous permafrost. Permafrost greatly influences the availability of water resources, as well as the selection and cost of utility systems.

1.3.1 Water Supply. Although water is generally an ubiquitous and free commodity, the development of a community water supply requires a considerable investment. Wells are usually the most desirable water source; however, they are generally not applicable in permafrost areas and even where wells are possible, the long winters can hinder recharge and limit the quantity of water available. Communities located on large rivers have unlimited quantities of water available but the short intense spring runoff may make the installation of a permanent intake expensive or impractical. Small rivers may cease to flow in the winter or poor water quality can often make distant lakes more attractive sources. The precambrian shield and permafrost provide impervious boundaries that result in innumerable lakes in an area that generally has precipitation levels similar to that found in desert regions. Many of these lakes have a limited recharge area and are quite shallow and freeze to the bottom in winter. Many others develope poor water quality as the ice thickens increases and impurities in the water are concentrated. This process can make the remaining water unpalatable without treatment. Thus, many initially promising water sources do not provide adequate year round quantities of water.

Northern communities were rarely founded with much consideration to the provision of utilities and some are outgrowing their initially adequate water supply. Distant and/or poorer quality water sources must be developed at high costs to provide sufficient quantity and a reliable year round supply.

Where permanent intake structures are not used, water storage is sometimes required to meet the community water requirements during the freeze-up and break-up periods of rivers or lakes normally used as water supplies. There are also communities, primarily in the Eastern Arctic, that do not have a convenient source of water during the winter (Foster, 1975). In such cases an earth reservoir or heated and insulated storage tank must be constructed to contain the entire winter's water requirements. This storage alone may have a capital cost of one to three cents per litre. These conditions can place a finite limit on the water available and water conservation becomes imperitive.

Water treatment, beyond simple screening and chlorination, is required at communities utilizing the silty river waters. Package physical-chemical treatment plants are commonly used. Hardness, iron, and other water quality constituants have also necessitated treatment at specific communities. Water conservation reduces the treatment plant capacity that is required but the greatest savings are usually in the reduced operating cost such as for chemicals and electricity. For example, electric power requirements are approximately 1 kW·h/1000L for coagulation, sedimentation and filtration (Watson, 1972) but for advanced treatment processes such as reverse osmosis, the energy requirements are much higher.

Northern utility systems usually require heating of the water supply to prevent freezing and sometimes to improve treatment operations. During winter, the near-freezing waters are often heated to 5°C before distribution, therefore, a reduction in water demand would reduce the heating requirements and costs.

1.3.2 Distribution/Collection Systems. There are generally three systems utilized to supply water and remove wastewater from buildings. These are:

a. individual haul;
b. trucked; and
c. piped.

The high capital cost of piping systems in permafrost areas ($400 to $1000/m) generally makes trucked water delivery and sewage pumpout more economical in existing Arctic communities with less than

1500 people (Cameron, Christensen and Gamble, 1977). Increasing the community density through better planning and multifamily housing or the elimination of fire protection in the design would drastically reduce the piped system costs. However, the low level technology and low capital and water requirements combined with the flexibility and local employment offered by trucked systems will ensure their utilization in most of the smaller, non-industrial communities and also within portions of many of the larger communities.

With trucked systems, water is delivered by insulated, usually 4500 L capacity rubber tired tanker trucks. Within new houses, a water tank of about five days storage capacity is provided along with an internal pressure system. A sewage holding tank large enough for approximately seven days wastewater production is located under the buildings, if possible, and at a location where there is easy access for the vacuum tank pumpout vehicle. The holding tank is preferably located close to the bathroom facilities so that a large volume of water is not necessary for the transport of wastewater in the drainage pipes. If the tank is located under the toilet, then a mechanical seal toilet that uses 0.5 L/flush is commonly used but where this is not practical conventional 20 L/flush toilets have been used.

One vehicle can deliver or collect approximately 30,000 L/day and the economic unit costs for trucked water and sewer service are $10 to $20/1000 L. A typical breakdown of the total annual cost is:

Labour	50%
Vehicle Capital	15%
Vehicle O&M	21%
Garage Capital	9%
Garage O&M	5%
Total	100%

The fixed costs are relatively low, therefore, there is little "economy of scale" and the total cost is directly proportional to demand. Thus, the monitary benefits of water conservation are easily calculated and very significant.

Individual systems such as wells and septic fields are not usually viable in permafrost areas; however, they are utilized in portions of the southern Yukon and Northwest Territories and in the northern part of the provinces. As with community systems, wells may have a limited yield and require expensive water treatment. Pumping requirements are usually low. The efficiency and life of a subsurface soil disposal system may be enhanced and its size reduced by the reduction in wastewater flow and by the elimination of human waste products from the septic system (Winneberger, 1974).

Conventional piped water distribution systems for small communities and subdivisions are primarily designed for fire flow requirements and peak demands. Also, the high cost of mobilization for northern construction often reduces the incremental cost of increased capacity. This does not negate benefits of water conservation but it may shift the emphasis to reduced operating costs and to deferred expansion of facilities and trunk mains.

Some northern piped systems have been designed intentionally or have resulted in the wasting of water. Bleeding of water into sewers has been practiced in Yukon communities such as Whitehorse and Dawson City and many Alaskan communities (Hansen, 1975). Freezing is prevented by the addition of warmer water and by maintaining a flow in the service lines and the mains. Resulting water consumptions are often 1500 L/person·d, but values as high as 10,000 L/person·d have been recorded. With expansion, increased pumping costs and treatment requirements, it has generally been found that other direct methods of freeze prevention are more economical, and new systems are not usually designed with intentional permanent bleeding. Another typically northern problem that has occurred is the overheating of water resulting in the wasting of water by those attempting to obtain cold water. This is common with utilidors that contain both water and sewer lines and central heating lines. Heat loss from the latter pipes prevents freezing however the inherent poor temperature control often results in excess heating of stagnant water in the mains. To reduce the risk of freezing, some northern water systems have been designed or operated at high temperatures and this also results in wasting of water. Naturally, where bleeding and excess heating occurs, any in-house water conservation would only yield energy reduction benefits from reduced hot water requirements. Both these situations have proven to be costly and are no longer being used for freeze protection in new installations. Remedial measures to eliminate bleeders in existing systems are being investigated (Armstrong and Given, 1979).

The whole concept of designing piped systems for fire flows in the north has been questioned (Gamble, 1977). Under northern conditions, the incremental cost is higher and the benefits appear to be lower than in the south. If better fire prevention, detection, and more appropriate fire protection and fighting methods were utilized, then whole communities or just residential areas could possibly be serviced by smaller diameter water mains which would be designed and sized primarily for consumption demands. The use of buffer tanks in each building would eliminate the peak design requirements and further reduce the size of the mains (James and Suk, 1977). Water conservation would play a significant role in reducing costs for these non-fire flow systems.

Both pressure and vacuum sewage collection systems have been used in the north (Ryan and Rogness, 1977). These non-gravity systems are particularly suited to permafrost and frost-susceptible soils because they can tolerate some pipe movement. They are viable solutions in areas where topography, permafrost, or rock restrict the layout and increases pipelaying costs. Vacuum systems have also been used within buildings and camps to overcome grade limitations and reduce water requrirements. Vacuum systems can utilize a special 1.5 L flush toilet, and pressure sewer systems can utilize low-flush toilets; therefore, water demand can be reduced with both these systems.

1.3.3 Sewage Treatment. The most common method of municipal wastewater treatment in the north is the use of a lagoon. A secondary level of wastewater effluent and reduced environmental impact of effluent discharges can be achieved by complete retention during the ice covered period followed by aerobic stabilization. The primary design criteria is the hydraulic loading and water conservation can therefore reduce the size and cost of a secondary lagoon.

Primary treatment plants are also designed hydraulically, but biological treatment plants are generally influenced more by the organic loading, which is the same regardless of dilution. Where bleeding treatment plants will require design modifications to treat the high strength wastes from vacuum or trucked pumpout systems or if water conservation is practiced, however, capital and O&M cost reductions will be possible.

1.4 Energy

Fuel oil is the primary source of energy in the Arctic. Barges deliver fuel from Norman Wells, NWT, to the western Arctic while the eastern Arctic is supplied from Churchill or Montreal. Other areas of the north are supplied by road, rail, winter road or even by air. Electricity is primarily generated and distributed by the Northern Canada Power Commission, a crown corporation. Typical oil-generated domestic electricity rates in 1978 for demands over the subsidized first 300 kW·h per month are:

Inuvik, NWT	9.5 ¢/kW·h;
Norman Wells, NWT	11.2 ¢/kW·h;
Frobisher Bay, NWT	13.4 ¢/kW·h;
Rankin Inlet, NWT	20.7 ¢/kW·h;
Grise Fiord, NWT	24.6 ¢/kW·h;
Lac La Marte, NWT	35.0 ¢/kW·h; (must fly in fuel); and
Old Crow, YT	18.2 ¢/kW·h.

Hydro power is used extensively in the Yukon, and in the southern NWT. Typical residential rates for over 500 kW·h per month are:

Whitehorse, YT	3.32 ¢/kW·h;
Carcross, YT	4.38 ¢/kW·h;
Yellowknife, NWT	4.66 ¢/kW·h; and
Haines Junction, YT	5.44 ¢/kW·h.

In contrast, the gas and coal generated electricity in Edmonton, Alberta costs approximately 2.05 ¢/kW·h for residential use in 1978.

Water conservation reduces energy requirements within buildings as well as for various aspects of the community utility system. Within the house, the main energy savings is due to reduced hot water requirements for shower and tub bathing, laundry, and washing. Utility system savings accrue from reduced energy for: preheating of water; less heat loss during storage; lower pumping costs; lower costs for operation of some treatment plants; and less fuel for the operation of trucked systems.

2 LITERATURE REVIEW

2.1 Water Conservation

The approach of most municipalities, utility system operators, and government has usually been to install facilities to provide the volume of water demanded by domestic, commercial, industrial and agriculturual users. There has been very little, if any, attempt to curb the increasing quantities demanded and, indeed, higher consumptions have often been encouraged. Water use research has been primarily concerned with demand forecasting rather than demand modification.

Perhaps a significant turning point in water use research was the household water conservation study by Bailey et al, (1969). This study reviewed the current qualitative and quantitative water requirements to determine areas where better water and waste management would be most beneficial. Bailey et al showed that water used for bathing and toilet flushing could be substantially reduced through the use of more efficient plumbing devices and that water reuse for toilet flushing was viable. Cohen and Wallman (1974) carried out a demonstration project to evaluate the methods outlined earlier by Bailey et al (1969). During this period the interest and publications outlining water conservation technology and hardware greatly increased including a summary by Sharpe (1974). A number of specific studies were published in the proceedings of a conference on water conservation and sewage flow reduction edited by Sharpe and Fletcher (1975).

Knowledge of the quantities and influences on water demand are basic to any study of water conservation. One of the most extensive studies of residential water use was published at John Hopkins University by Linaweaver et al, (1966). Many of the recent studies on water conservation and individual household wastewater treatment have recorded water use for various appliances, fixtures and functions. Economic and statistical analyses of water use and pricing policies have been carried out by various authors including Grima (1972) and Hollman (1973). Chan et al, (1975, 1976) formulated a computer model to study the cost effectiveness of pricing schemes and water saving devices. Milne (1975) reviewed the social and psychological aspects of water use and technology and emphasized life-style and behavioral modifications in reducing residential demand.

The available water conservation appliances and devices have been documented in a number of reports including those published by the Washington Suburban Sanitary Commission (1972), Milne (1975) and North Marin Country Water District (1976). Toilet alternatives for developing countries and for northern Canada were summarized by Rybczynski and Ortega (1973), Grainge et al, (1971) and Orr and Smith (1977). Technology developed for vacation homes, recreation vehicles, aircraft and ships (Rosenbusch, 1973) has also found application in residential buildings. The use of water reduction and recycle technology from space research efforts has been studied (Hypes and Collins, 1974) and integrated household utilities which include recycle have been demonstrated (Besik, 1974). Consumer interest in water conservation has recently spawned evaluations of toilet and shower devices by Popular Science (1977), and Consumer Reports (1978).

Recent cases of water shortages and limitations imposed on expansion of utility systems have greatly increased the interest and publications related to water conservation. Since 1972, the Washington Suburban Sanitary Commission (1972, 1973) has promoted voluntary water conservation through a public education campaign, and the distribution of free water saving kits. Plumbing codes and rate structures to hold down consumption were also instituted. During the recent water shortage in parts of California these tactics were not sufficient and high rate penalties were imposed on consumptions exceeding each customers allotment. By these measures, Marin Country residents reduced consumption by 65% and post-drought consumption is still 45% below pre-drought levels (Consumer Reports, 1978).

Appendix J contains abstracts of some of the most significant reports in the area of water conservation.

2.2 Energy Conservation

Measures to reduce water demand have generally received considerably more attention than the concomitant energy reductions they make possible. However, studies which do not consider the energy savings will substantially underestimate the total benefits of water conservation.

Baker et al (1975) showed that the major energy savings come from a reduction in household hot water used for showers and laundry. They estimated the annual energy requirements per residence for a model community of 10,000 persons at: 57 kW·h for water supply, treatment, and distribution; 84 kW·h for activated sludge sewage treatment; and 8634 kW·h for hot water heating. They calculated that stringent water conservation methods that would reduce water demand by 68% would also reduce residential hot water heating requirements by 60% and water supply energy costs by 70% for an annual saving of 5044 kW·h per residence. These residential savings may be somewhat optimistic since other sources have estimated that typical annual household water heating requirements at 4000 kW·h (Energy Mines and Resources Canada, 1975).

Energy requirements for water and wastewater treatment depend very much on the process used. A manual for calculating water treatment costs prepared by Watson (1972) estimates that for coagulation, sedimentation, and filtration, the electrical requirements were 0.8 $kW \cdot h/m^3$. Simple chlorination uses very little if any energy but advanced treatment processes such as reverse osmosis or distillation require approximately 2.5 and 12 $kW \cdot h/m^3$, respectively, and water conservation would effect significant savings. Smith (1973) provides electrical power consumptions for various unit operations for municipal wastewater treatment systems while Tchobanoglous (1975) concentrates on alternatives appropriate for small communities. Power requirements for facultative lagoons are usually nominal while a biological secondary treatment plant may require 0.04 to 0.18 $kW \cdot h/m^3$ depending upon the process.

Treatment processes are generally more efficient in terms of removal of pollutants when the sewage strength is significantly increased. The benefits depend on the characteristics of the process and the wastewater. The capacity requirements and operating costs for winter retention lagoons, primary treatment, and physical/ chemical treatment processes which are hydraulically designed could be significantly influenced but energy requirements for biological proceses may not be significantly reduced. Various wastewater treatment alternatives have different energy requirements and some processes are more appropriate for treating strong effluents. Therefore, although water conservation and energy requirements are very important in process selection, they may not have any further significance once the process has been selected. Where water conservation reduces the organic loading, such as through the use of compost toilets or in-house treatment and recycle, all treatment process will have reduced capacity and energy requirements.

In northern areas it is often necessary to heat the water to prevent utility system freezing. A $5^{o}C$ temperature increase requires 6 kW·h/1000L or about 1000 kW·h/a to heat the water used by a typical household on a piped system if heating is required for half the year. For the same situation, a fuel oil fired boiler at 80% efficiency would require 0.7 of fuel oil to heat 1000L of water or about 115 L of fuel oil per household per year. Thus, where pre-heating of water is necessary water conservation will significantly reduce the energy requirements.

Energy requirements for other aspects of community or individual water and sewer systems, such as for pumping or operating trucks, can also be reduced. These depend on the distances involved. For example, trucks consume approximately 3.5 L of gasoline for each 1000L of water delivered or sewage collected when the source or disposal points is 1 km from the community centre. Muller (1975) analyzed energy reductions through the use of more efficient water heaters, insulated hot water tanks and pipes, and heat recovery as well as low water use showers, washers and faucets.

Water conservation will reduce the size and operating requirements of many utility system components. Therefore reductions in the energy requirements for the procurement, manufacture, transport and so forth of construction and operating materials, such as steel and chemicals, will also be realized. From a national or global resources perspective these reductions in material requirements can be considered an energy conservation aspect of water conservation even though the costs for this energy are included in the costs of the materials.

2.3 Water Demand

Within Canada only about 10% of total water withdrawals are for municipal and rural water supplies (Tate, 1977). Other uses include manufacturing, mining, agriculture and non-hydro electrical production. This small municipal portion underscores the significance and large expenditures attributable to municipal water supplies. Also, this figure does not indicate the regional or local water use patterns. Within portions of the Canadian north water withdrawals by communities are more significant and industrial and agricultural requirements must be assessed on an individual basis. Because of the small populations and great distances between communities, the water supply or disposal practices of one community seldom affect those of other communities and communities can usually be considered on an individual basis.

Total water use within a community is a function of many variables. Population can often be used as a good indicator of the size of any non-domestic commercial and industrial water requirements. For example, a community of 500 would generally be exclusively residential while in a community of 10,000 the non-residential water demand is typically 50% of the total. Figure 1 from Christensen and Reid (1977) indicates typical ratios of residential to non-residential water demands for various sizes of NWT communities. They made this curve independent of the community utility system, that is trucked or piped, since it was expected that the ratios would remain the same. Thus, the total community requirements can be estimated from the population and the per capita domestic requirements.

The literature contains many estimates of community and household water use. Some of these are compiled in Table 1 to illustrate the wide range that can be expected, depending on the local conditions. There is no "average" household water consumption, however, it is clear that a "normal" indoor residential consumption for a family of four should not exceed 250 L/person·d for a piped system and 115 L/person·d for a trucked system. Where consumptions are significantly different from these, one should look for explanations within the utility system, households, the pricing policy, and other areas. For example, a piped system with

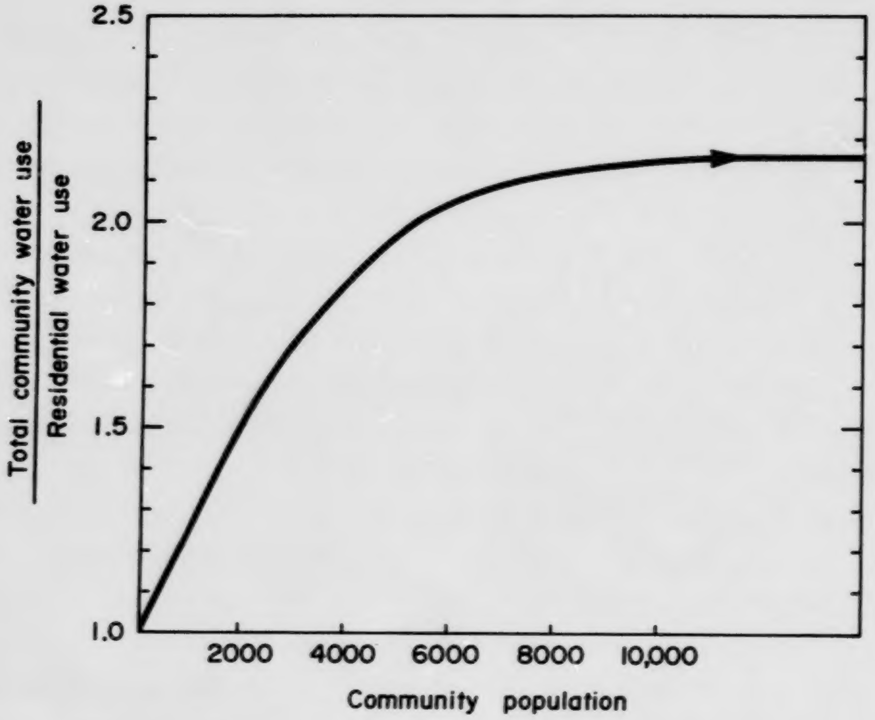

FIGURE 1. COMMUNITY WATER USE FACTOR (Christensen and Reid, 1977)

bleeders may exceed 2500 L/person·d, while houses without internal plumbing may use only 10 L/person·d. Given the same utility system and internal plumbing it is reasonable to assume that indoor household consumption in northern locations would be similar to values reported for southern residences. Outdoor uses are more difficult to predict. In areas with hot, dry climates outdoor uses, primarily lawn watering, are sometimes greater than the indoor uses. Chan et al (1976) proposed an additional 95 L/person·d as a reasonable value. Outdoor water use in northern communities may not be as significant due to the short summer and fewer lawns.

Water is not used at a constant rate throughout the day. Typically, there is a morning peak between 0700 and 0900 h and an evening peak between 1700 and 1900 h (Figure 2). Instantaneous household demand may be 10 to 50 L/min but peak hourly demands are generally 3 to 4.5 L/min (Anderson and Watson, 1967). There are also variations of demand within the week of up to 300%, due primarily to laundry habits, as well

TABLE 1. WATER CONSUMPTION LITERATURE SUMMARY

CONSUMPTION L/person·d	COMMENTS	REFERENCE
240	1963-1965 residential, annual metered average, western U.S.A.	Howe & Linaweaver, 1967
167	average, 18 residential homes, Louisville,	Anderson & Watson, 1967
68 - 261	range	
263	1968 residential, unmetered average, Toronto	Grima, 1972
171	1968 residential, metered average, Toronto	
114 - 189	range for residential	Wallman, 1972
330	January residential, Phoenix, Arizona	Whitford, 1972
1325	July residential, Phoenix, Arizona	
208	July residential, Baltimore, Maryland	
253	sewered households	Cohen and Wallman, 1974
167	households connected to septic tanks	
168	mean, 19 rural households	Ligman et al, 1974
31 - 615	range,	
153 - 182	95% confidence interval	
169	average of 6 households	Bennett, 1975
161	average of 11 rural households	Siegrist et al, 1976
154 - 168	90% confidence interval	
190	1972-73-74 residential, metered average, Edmonton	Gysi and Lamb, 1977*
217	1972-73-74 residential, metered average, Calgary	
420	1972-73-74 residential, unmetered average, Calgary	
202	1975 residential, metered average, Edmonton	
210	1975 residential, metered average, Calgary	
465	1975 residential, unmetered average, Calgary	
236	1977 Edmonton, metered, 3.5 persons/house	Betker, 1977
625	1975, mean for 2780 municipalities in Canada	Environmental Protection Service, 1977
485	1973, Inuvik, serviced portion of community	Associated Engineering Services Ltd., 1973
1680	Whitehorse, residential with bleeders, average	Stanley & Associates Engineering Ltd., 1974
1135 - 2500	range	
530 - 6200	1973 survey, 20 Alaskan communities (high range use bleeders)	Hansen, 1975
430	1975, Yellowknife, total community	Environmental Protection Service, 1977
	Yellowknife trucked households, 2.85 persons/house,	Cameron, 1977
118	mean	
45 - 295	range	
70 - 167	95% confidence interval	
9	no plumbing, N.W.T. communities	
243	mean, 200 - 1300 man camps	Murphy et al, 1977
160 - 410	range	
200 - 286	95% confidence interval	
86	18 man camp washcar with vacuum toilet (kitchen wastes excluded)	Given and Chambers, 1976

*reported total household consumption values were divided by average 4 persons/house.

as seasonal variations, due primarily to lawn watering. Demand fluctuations within the day are more significant in smaller systems or communities. Suggested values for peak daily and peak hourly demand are 250% and 450% of the annual average daily demand. Community distribution piping systems are designed to meet these peak demands. Water conservation not only reduces the total volume of water used but it also moderates the peak demands in the same proportion, as illustrated in Figure 2 (Bennett, 1975). Thus, the capacity requirements of most components of a piped water system can be reduced through conservation. Piped sewage collection systems also experience flow patterns similar to water systems but these are usually moderated and can be influenced by infiltration. The benefits of water conservation will generally be relatively less for piped sewage collection systems compared to piped water distribution.

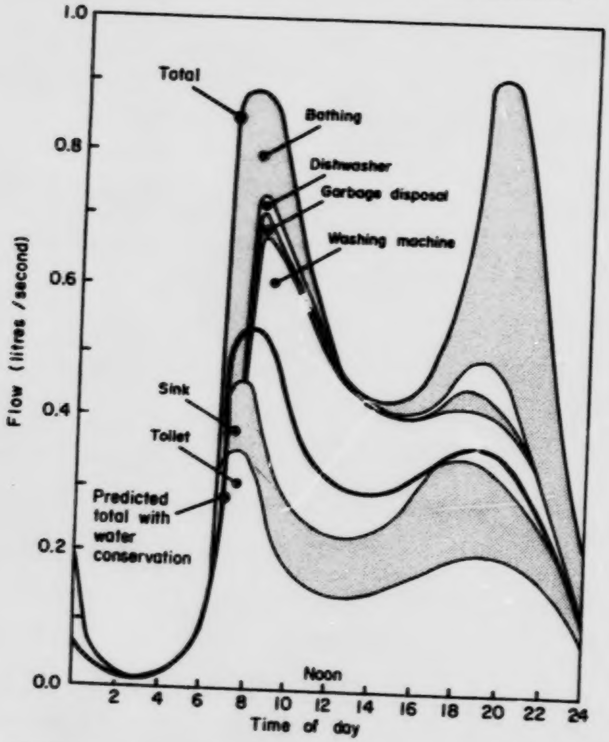

FIGURE 2. DAILY HOUSEHOLD WATER USE PATTERN AND EFFECT OF WATER CONSERVATION (Bennett, 1975)

Water is used within the household through various fixtures and appliances for a number of functions. Various studies which measured household water use distribution are summarized in Table 2 and the mean values are illustrated in Figure 3. The reasonably narrow range and standard deviation indicate that the mean values presented should be applicable for estimating water use and in water conservation calculations. Naturally there may be significant variations within individual households. This data is derived from houses served by piped or individual systems. Similar data is not available for fully truck serviced houses; however, at this time it seems reasonable to assume a similar distribution for houses which have full standard plumbing. Since water for the toilet (40.0%); bathing (29.7%), and laundry (14.6%) make up 84.3% of the total water use, these are the prime areas where water conservation methods are considered.

TABLE 2. HOUSEHOLD WATER USE DISTRIBUTION

	Bailey et al., (1975)	Bennett (1975)	Besik (1973)	Haney & Hamman (1965)	Laak (1975)	Ligman (1972)	Murray & Reeves (1972)	Wallman (1972)	MEAN	RANGE	STANDARD DEVIATION
TOILET	39.2	33.0	38.0	45.0	47.0	41.0	41.0	36.0	40.0	33.0 - 47.0	4.6
BATHING (Bathroom sink, lavatory)	31.4 3.1	24.0	34.0	30.0	21.0	26.0	37.0	27.0 4.0	29.7	21.0 - 37.0	5.6
LAUNDRY	13.7	27.0	12.0	5.0	18.0	19.0	4.0	18.0	14.6	4.0 - 27.0	7.6
Dishwash, Garbage disposal KITCHEN Drinking, Cooking	5.9 4.7	16.0	10.0 3.0	6.0 3.0	9.0	10.0 3.0	6.0 5.0	13.0	11.8	9.0 - 16.0	2.4
UTILITY SINK	2.0		3.0	4.0		1.0	3.0	2.0	1.9	0 - 4.0	1.5
MISCELLANEOUS				7.0	5.0		4.0		2.0	0 - 7.0	2.9
TOTAL	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %		

2.4 Influences on Water Use

2.4.1 Utility System and Household Plumbing. The method of water distribution and wastewater collection is very significant in establishing the water consumption. Communities in the north with individual haul or delivery to houses without plumbing use only about 10L/person.d which is not much more than the 2 L/person·d or so necessary to sustain life.

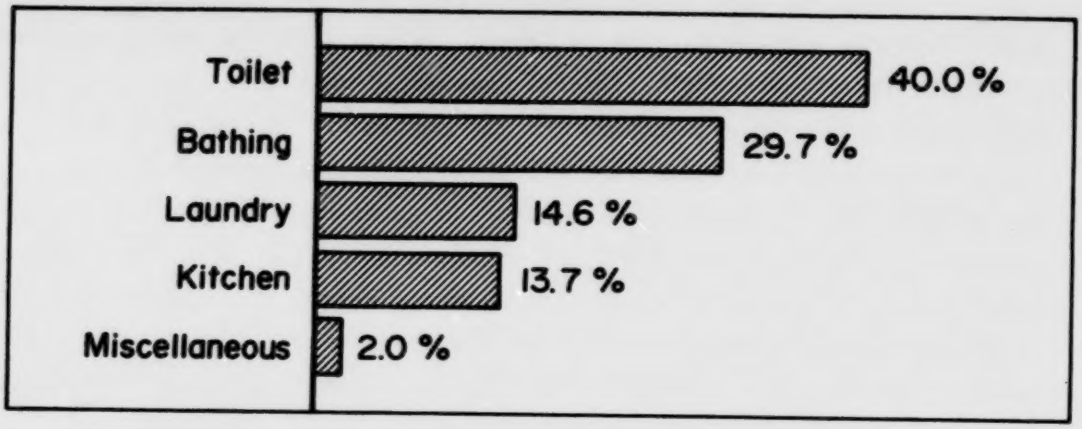

FIGURE 3. HOUSEHOLD WATER USE DISTRIBUTION

Such small amounts are a restraint to good health and are generally considered substandard (White and Seviour, 1974). As an alternative to conventional utility systems for small unserviced communities, the Alaskan Village Demonstration Project provided a central facility with laundry and showers as well as safe water supply and integrated waste management system (Puchtler, et al, 1976; Reid, 1977). Although household water use was only 5.5 L/person·d, significant health benefits were observed. Recycle of greywater for laundry and low water use toilets was used to reduce water requirements at the central facility to 17 L/person·d.

Water consumption increases dramatically in houses which are equipped with pressurized hot and cold water plumbing systems including bathtubs, showers, toilets and sinks and where an organized community utility system exists. Buildings that are served by trucked water delivery and sewage pumpout service consume much less water than those connected to a piped system. This is indicated by the data in Table 1 and illustrated in Figures 4 and 5 for 33 private houses equipped with full plumbing that are and located in an area of Yellowknife, NWT which is serviced by trucks. Examination of the data indicates that a four person family uses 95 L/person·d. While a similar house on a piped system would consume about 225 L/person·d, which is 2.35 times as much. In the Yellowknife case, the truck serviced consumers pay the same rate for water as those on a piped system and they do not generally use low water use fixtures. Buildings with individual pressure pumps typically operate at low water pressure of 175 to 275 kPa which would account for some reduction in consumption. Water, however, is only delivered twice weekly, except in emergencies, and water holding tanks (cisterns) must be a minimum of 1800 L. Because of this somewhat restricted supply of water to and within the house, most residences are conscious of their water use and particularly water waste. Leaky plumbing and uncontrolled running of water are soon noted and corrected. Water using actions from obtaining a glass of water to bathing to doing the laundry are all performed to maximize the available water and maintain a reserve for essential uses. Toilets are not used as garbage cans and often urine is not flushed after every use. During parties some people place a sign by the toilet saying "when it's yellow let it mellow - when it's brown flush it down." These adjustments in behaviour and only minor changes in plumbing indicate the reductions in water use that are possible. In this same group of houses, the range of water demand was from 45 to 295 L/person·d, indicating that, while some households must severely limit themselves, others are not greatly influenced by the truck water delivery system. For all of the houses, the installation of low water use fixtures and appliances could further reduce demand and provide a more reliable, aesthetically appealing, and economical system.

Households on piped systems use large volumes of water, partly because of the seemingly unlimited quantity of water available. Other factors that contribute to high demands in northern communities include the bleeding of water to prevent freezing of water and sewer lines and overheating of water, particularly in utilidors containing central heating lines. Both of these are undesirable and inefficient features which are unnecessary in new northern utility systems. Existing systems require administrative, technical and economic analysis to indicate remedial actions to reduce or eliminate bleeding (Armstrong and Given, 1979).

Gravity sewer systems require minimum velocities to prevent solids deposition. Generally, a velocity of 0.60 m/s is adequate. Cole (1975) calculated the impact of low flow toilets on house connections

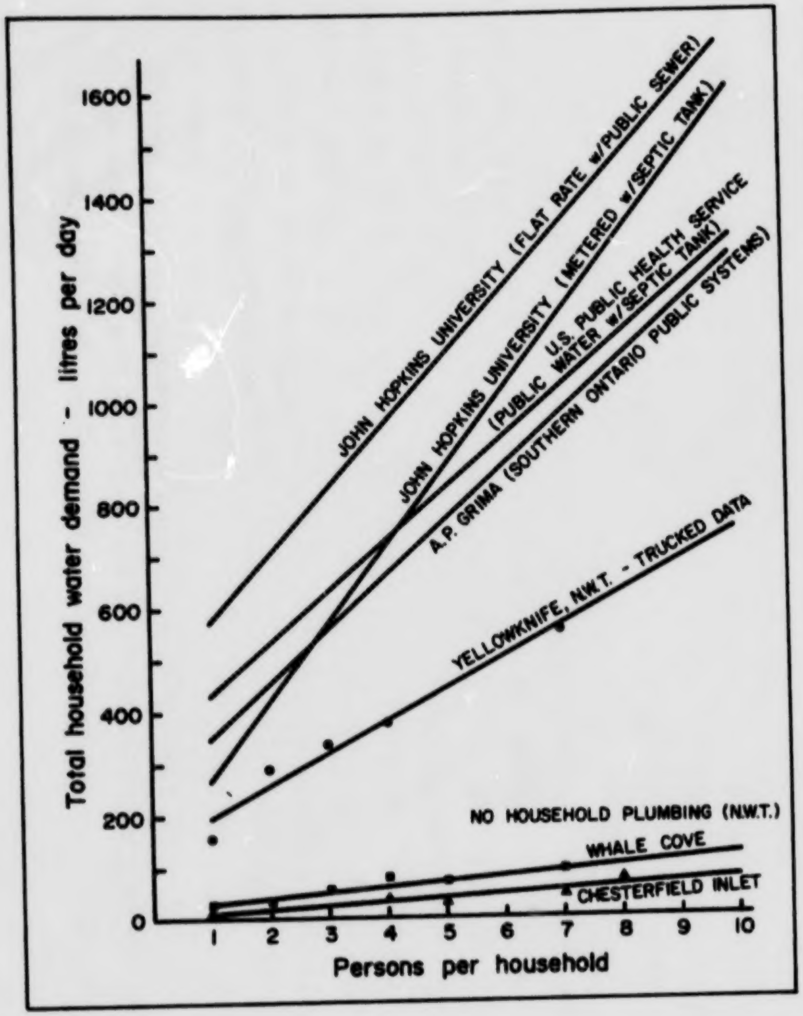

FIGURE 4. SUMMARY OF DAILY HOUSEHOLD WATER DEMAND

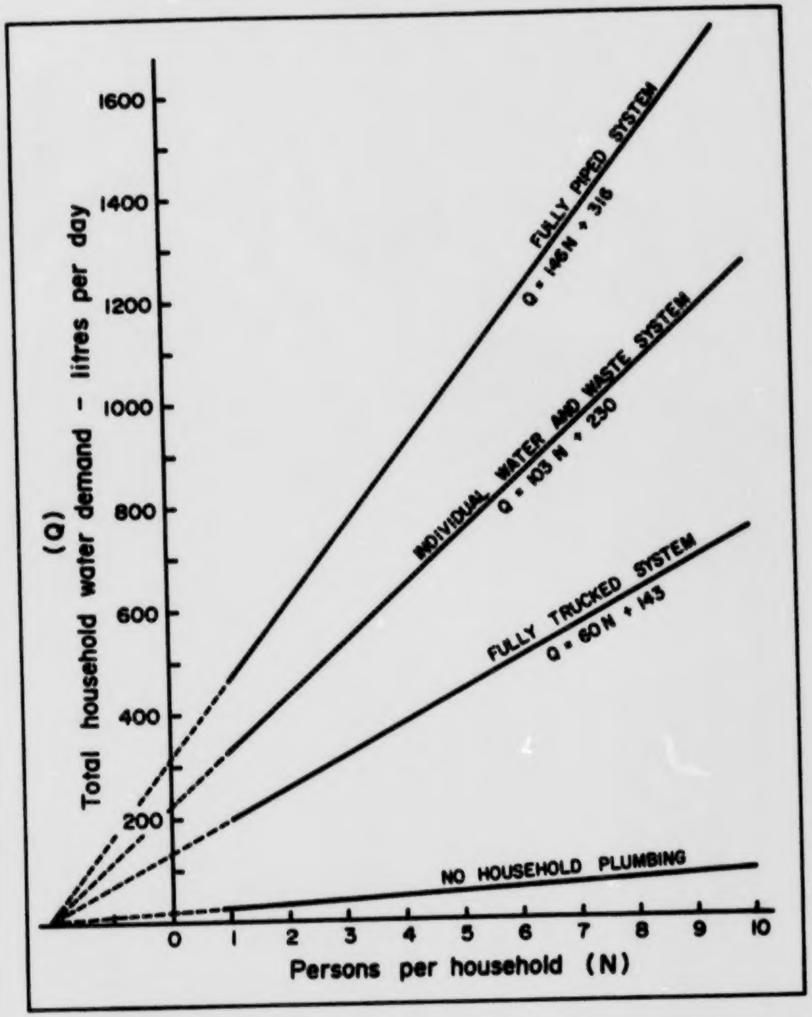

FIGURE 5. EXPECTED DAILY HOUSEHOLD WATER DEMAND

and sewer mains and Konen and DeYoung (1975) tested conventional and low flow toilets to determine their performance and hydraulic characterisitcs. They showed that the discharge (flush) time is as significant as the volume of water used. Because of their high discharge rates, both the European 6 L toilet and the compressed air assisted toilets which use only 2 L/flush should perform adequately when 100 mm diameter house connections are used with a standard 2% slope. Non-gravity sewer systems can also be utilized. Both vacuum and pressure sewer systems have been constructed in Alaska (Rogness and Ryan, 1977; Ryan and Rogness, 1977). Vacuum systems have also been used in a northern construction camp (Given, 1977) and within isolated facilities in the Arctic. These utilize a vacuum to transport the wastewater in slugs to a central collection tank (Averill and Heinke, 1974). A special 1.5 L flush toilet is available for use with vacuum systems. With pressure sewer systems each house or cluster of buildings discharge through conventional plumbing into a holding tank which contains a grinder pump to pump the wastewater into the collection main. Complete compact package systems are available for this purpose. Alternatively, a conventional septic tank with sump pump at the outlet has been utilized. Because of the short length of gravity sewer to the grinder pump, low flush toilets are appropriate in buildings serviced by vacuum or pressure sewer systems. Both pressure and vacuum systems use small diameter, 40 to 100 mm, sewer lines. They can be installed relatively independent of grade, thereby allowing shallow burial, reducing excavation cost, and some movement due to frost heaving or thaw settlement of permafrost. They also facilitate the servicing of undulating areas. These latter characteristics are their primary advantages since water conservation can be achieved by a number of other low-flush or non-water using toilets. Where water supply is critical, trucked systems may be more appropriate due to their lower water requirements.

Utility system water conservation alternatives are further discussed in Appendix H.

2.4.2 Family Size. Total household water use increases as the number of persons living in the house increases but the per capita consumption decreases. This is partly because there is a "overhead" quantity of water used in occupied households (Andrews, et al, 1970). Certain household tasks are performed with about the same amount of water regardless of the number of occupants. Lawn watering would be an extreme example of this. The age composition of persons within the household also influence water use. Adults generally use the largest quantities of water although teenagers are often identified as heavy users of hot water.

The variation in consumption with persons per household for piped, individual and trucked systems is shown in Figure 3. Figure 4 suggests design values based on the average of the values in Figure 3. Doubling the number of persons per household increases the total consumption by 40 to 70%, depending on the initial household size.

The economics of water conservation are affected by the family size because the family size influences the total building water demand and the number of times a particular fixture or appliance is used. Since most water conservation devices entail an additional capital expenditure but lower operating cost, they are more economically attractive where they would be used more frequently. For example, a front load laundry machine which may not be economical for a couple could afford considerable savings for a family of six.

2.4.3 Socio-economic Status. Families or persons with higher socio-economic status use more water than those with lower socio-economic status (Larson and Hudson, 1951; Linaweaver et al, 1967; Grima, 1972). The socio-economic level is usually expressed in terms of the level of income or market value of the home, but housing type and size have also been used. In some cases, the socio-economic level may be indicative of a different type or level of water and sewer service and it is usually an indication of the water using fixtures and operations of the household. The increase in water use is primarily attributable to less essential functions such as watering lawns, filling swimming pools, washing cars, taking longer showers (with high water using massage sprays), water cooled air conditioners, garbage disposers and automatic dishwashers. Families in lower socio-economic levels often cannot afford these amenities, therefore, they use less water. Another reason cited for the difference in demand is that if families spend the same proportion of their income on utilities, then those with higher income would naturally use much more water.

Changes in socio-economic level will gradually result in changes in water consumption; however, established habits are difficult to change. For example, native people moving into a house with full plumbing often do not initially utilize large quantities of water. Conversely, people returning home from working or boarding schools in the large fully serviced communities of the north or people moving to the north who are accustomed to a "southern" utility system with cheap water may have difficulty in adjusting their water use habits to the limitations or high costs of utility systems in the small northern communities.

Socio-economic status is significant in estimating water demand but since it is only an indirect measure of water use it cannot, and should not, be used to alter demand. A better approach would be to publicize methods of reducing waste and by promoting water and energy conservation methods that provide economic benefits to the individual. Promotion of the conserver ethic may alter our society from thinking that higher water use and even waste is necessary or even a desirable indicator of a higher socio-economic status.

2.4.4 Climate. The influence of climate on water use is mainly due to outdoor uses including lawn watering, gardening and swimming pools. Increased bathing and water cooled air conditioners may also be a factor. The American Water Works Association (1973) report on water use indicates that the amount of rainfall significantly influences sprinkler use in areas receiving between 13 and 102 cm of rain annually. Areas receiving less rainfall must rely on irrigation and in areas receiving more than this, the normal rainfall is generally adequate to supply lawn and garden needs. Seasonal and periodic climatic changes such as a dry year or hot spell can significantly alter the normal conditions and the water demand. This is particularly true where a flat rate is charged for water but climatic influences are modified depending on the unit price of water. The number and size of lawns, gardens and parks in a community also influence the water demand since these variables, along with the climate, determine the water requirements for sprinkling.

Water use for lawn watering is higher in the dryer west than in the relatively humid east (Linaweaver et al, 1967). In the western United States, though varying widely, 30 to 50% of residential requirements are for outside uses. The recent drought in California prompted a review of water conservation methods for lawn and garden watering (North Marin County Water District, 1976). These include watering tips to optimize the effectiveness of the water applied such as by using slow, intermittent applications, sprinkler systems that reduce waste, selection of plants and grass that reduce water requirements and low water use landscaping. These and other methods to reduce outdoor water use are mentioned in Appendix F. Because of lower outdoor water uses in the north these methods are not elaborated on in this report.

In the past, air conditioning and refrigeration imposed substantial demands on water utility systems. With the conversion of air conditioners to electric and gas cooling, the use of water for cooling is no longer a significant water use factor. The dry air prevalent at low temperatures will require more water to provide a desirable relative humidity in northern buildings.

2.4.5 Metering. A method of determining consumer water use is necessary to administer the various methods of charging for water and sewer service except where a flat rate charge is levied. For piped systems, a water meter is installed within each building, and for vehicle systems a meter on the truck is used. The volume measured for water demand is also utilized to indicate the volume of wastewater generated since meters for sewage flow are expensive, often impractical, and usually redundant. The recording of household meter readings is only done periodically, as infrequently as annually, by the utility system operators. Intermediate readings for monthly billing can be estimated or recorded by the consumer and mailed in to the utility operators.

Metering itself is not a price or rate structure; however, it implies that the price charged is based on the volume of water used.

Without metering, the same flat rate is charged regardless of consumption and there is no incentive, economic or otherwise, for the consumer to reduce water use. This is particuarly evident for outdoor water uses such as lawn watering. Where water is not metered summer water demand may be three times that of winter. This can significantly increase the peak demand and therefore the capacity requirements and capital outlay for a utility system. Although lawn watering may not be as significant in northern communities, other characteristics such as bleeding are comparable and can be much more significant than law watering.

Utility systems that rely on bleeders are almost always unmetered and a flat rate is charged. Water demand is many times the normal domestic consumption (Table 1). Some bleeders are left operating all year. During extended cold spells that increase the risk of freezing, water demand will increase as consumers open taps to increase the flow. Radio stations in Anchorage, Alaska inform the listeners when to bleed water (Ryan, 1978). Where services are unmetered, the consumer is in fact discouraged from installing and operating alternative freeze protection systems. For example, in some areas of Whitehorse, Y.T., service lines must be heat traced and bleeders are illegal; however, a flat rate is charged and the temptation to bleed water from a tap at no cost rather than to turn on an electric heating cable is often overwhelming (Ellis, 1978).

The installation of meters makes the consumer aware they are being charged for each unit of water consumed and provides an economic incentive to conserve since water bills can be reduced. Boland and Hank (1971) report a reduction in indoor and outdoor water demand of 36% and 50%, respectively after metering and unit pricing were initiated in Denver, Colorado. In Calgary, Alberta, consumers were offered either a flat or metered rate and although the annual bills were almost identical, Kellow (1970) found that those electing the flat rate system used almost twice as much water as the metered users. There are numerous other studies which show a lower water use where metering is used. The long term reduction may also depend on the price charged. Grima (1972) contends that metering per se need have no impact on residential water use since it is the variable price associated with metering that results in the response by consumers. There are of course many individual exceptions; however, there is enough evidence in the literature to suggest that a total water use of about 30 to 50% higher in flat rate areas can usually be expected. The extra demand is usually a result of seasonal peaks due to excess lawn watering and wastage.

The installation of meters facilitates the management of water use and supply and the equitable distribution of utility system costs. Unlike other policy alternatives open to utility system operators, the introduction of metering involves some direct costs. These include the purchase and installation of meters, the recurrent cost of meter reading and maintenance, and the increased administrative cost in formulating and collecting the variable consumers' bills. The arguments for and against metering are often emotional rather than analytical or economical. Coelen (1975) evaluated the relative effects and costs of metering, hence pricing policies, on consumer behaviour. He found that because metering entails expenses it is not always justified and is relatively less justified in communities with declining populations. The economics of water metering must be looked at for each utility system and the expected short and long term benefits compared to the costs associated with metering. Most studies clearly show that there are overall economic and administrative benefits to metering, particularly for new construction. Over 90% of municipalities in the U.S. have residential water meters (Hirshleifer, 1960). Those municipalities without metering are usually the smaller communities, with New York City being a notable exception. Dayton (1974) analyzed water rates in British Columbia and found that 80% of the communities with less than 1000 persons had no meters while all communities over 10,000 persons had some form of metering.

Some small communities in the north may also find that metering is not appropriate or cost effective. This may be partly due to the extra initial capital and meter reading costs; however, the shortage of skilled maintenance and administrative staff and fewer tangible benefits from metering may be more significant. Conventional piped systems in small communities are often designed to meet minimum capacities, usually determined by fire protection requirements, which are far greater than normal consumption demands. Therefore, unless there is a water supply problem, water demand reductions through metering only reduce the variable operating costs of the utility system. These may be significant where there are treatment and heating requirements. With trucked systems the variable costs are dominant, and metering is much more economically attractive and is usually essential to make the system viable. In some cases, a unit charge for water and sewage service may not be an appropriate or equitable method of distributing costs, therefore, metering would be unnecessary.

In many cases where a unit price and metering are not presently advantageous in terms of economics or management, it may still be prudent to have meters installed in new buildings since it is much more difficult and expensive to install them at a later date when the benefits of metering may become evident but the high capital cost to install meters would be discouraging. Also, attempts to initiate metering after the fact often evokes resistance from consumers who perceive this as a loss of freedom.

A degree of water conservation may be achieved without metering through plumbing codes, public education and other methods. These may not be successful without metering because the consumer does not receive any direct economic benefit from reduced demand, except for in-house energy savings for hot water heating.

2.4.6 Price and Elasticity. In classical economic theory, the price elasticity of a commodity is a measure of how the consumer will respond to changes in its price. If a change in price results in a significant change in demand then the demand is deemed elastic. On the other hand, demand is inelastic if a large change in price leads to only a small change in the demand for that commodity. Consumer response to changes in the price of water will depend on the present uses of water, the existing price level, the portion of consumer income spent on water, and the availability and cost of methods or technology to substitute or reduce the requirements for water. This is, of course, only true if water is metered and the consumer is charged accordingly.

Various water demand studies disagree as to the degree of elasticity of water demand with price (Hanke, 1978). Howe and Linaweaver (1967) found that indoor domestic demand was relatively inelastic with respect to price for metered residences and not significant for apartments and residences with a flat rate or septic tanks. The price elasticity for metered buildings connected to a public sewer was approximately -0.23 and doubling the price from 5 to 10¢/1000L would result in only a 10% reduction in demand. An analysis for summer sprinkler demand for this type of building in the humid eastern and dry western areas indicated price elasticities of -1.6 and -0.9, respectively and doubling the price from 5 to 10¢/1000L would result in a 66% and 39% reduction in demand respectively. Grima (1972) reported a price elasticity of -0.75 for water use in the winter and -1.07 for the summer for communities in the Toronto area. These results are illustrated in Figure 6. For a "new" community, Grima estimated that doubling of the price would result in a 52% reduction in the annual demand.

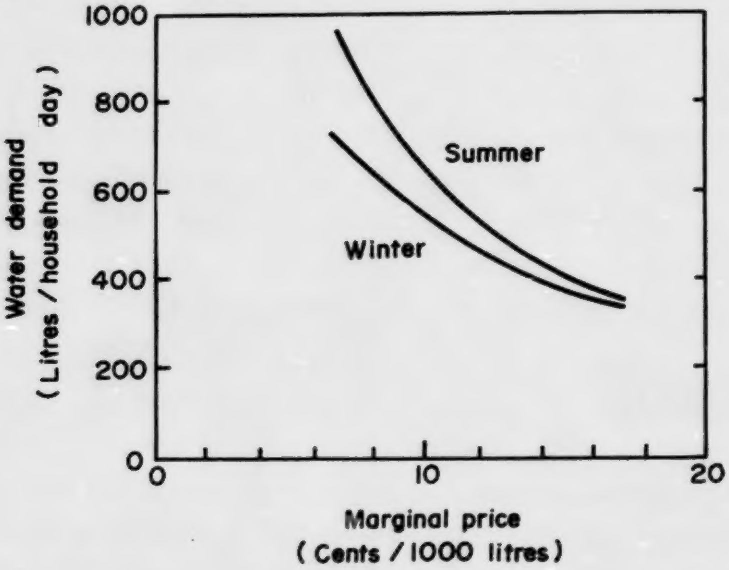

FIGURE 6. PREDICTED DEMAND FOR RESIDENTIAL WATER IN THE TORONTO REGION DURING SUMMER AND WINTER FOR VARIOUS PRICE LEVELS.

Milne (1976) argued that even though some people would theoretically be expected to reduce their consumption in response to a price increase, it is doubtful that they would. The primary reason for this is that the amount of money spent on water represents a very small portion of total family income. Expenditures for water and sewer services are often less than 1% of total income and most consumers do not even know how much they pay for water, only that it is the lowest of all the household utility bills. Milne (1976) concluded that since poor people cannot cut their consumption and affluent people probably will not, simply increasing the price will not be an effective means of reducing residential water consumption. This implies, however, that water is an essential commodity without substitutes and that all water use serves some consumer purpose. Clearly this is not true. The "essential" portions of residential water use for drinking, cooking, washing and other functions are probably less than 50 L/person.d and water conservation technology is available to bring this about. Much of the residential water consumption is wasted through consumer ignorance or indifference and inefficient household appliances which require excessive quantities of water. A high enough price will eventually bring about a reduction in water requirements and demand; firstly by a reduction in waste, secondly by a reduction in non-essential uses and finally by the utilization of economical water conservation technology. Other incentives and public education are probably necessary or at least desirable in conjunction with price changes. In some cases, these may even be sufficient in themselves; however, in order to persuade people to reduce consumption, some financial benefit or incentive must usually be associated with conservation. Grima (1972) argues that price itself can be effective at manipulating peak and annual demands and is one of the few tools at the disposal of the utility system managers. In a short term crisis situation a price increase alone may not be effective or equitable but in the long run it can be effective at reducing demand.

2.4.7 Rate Structure. The rate structure and price can be significant in establishing water demand and therefore it can be selected to reduce consumption and minimize costs. Descriptions and analyses of the various rate structures are presented in Appendix A. They are summarized in Table A-1 and illustrated in Figure A-1. They include: flat rate (constant price per month); uniform rate (constant price per litre); declining block (decreasing price per litre); increasing rates; and seasonal pricing. As indicated in the previous discussions on metering, consumers who pay a flat rate usually utilize 30% to 50% more water than metered customers since there is no incentive to use water efficiently. With all of the other rate structures, the cost of water and sewer services can be equitably distributed and the water demand can be influenced to some degree. With respect to these factors declining block is the poorest; the increasing block is good; uniform rates are fair; and seasonal and peak load rates are also fair and can be applied in conjunction with any of the other rate structures.

With the use of a detailed economic model Chan et al (1976) showed that, with respect to water demand, the rate structure itself was only significant to the extent that it established the marginal price. Results of their analysis are presented in Table A-2. At equal marginal prices the demand was the same regardless of the rate structure. With the notable exception of an unmetered flat rate, any unit price scheme can equitably return adequate revenue while facilitating water conservation and encouraging efficiency, providing the unit price reflects the actual cost for that service.

2.5 Pricing Policy

Details on pricing policy are presented in Appendix A and summarized here. The primary purpose of a rate structure and price is to recover adequate revenue. In order to facilitate economic efficiency the rate structure and price should reflect the actual long term marginal cost function of the utility system. Unfortunately it is impractical to precisely determine this function, particularly for piped systems, and administrative practicalities and subsidies can distort or even dictate the pricing scheme and the price. For heavily subsidized utility systems and in small communities it is tempting to charge a flat rate in order to reduce administrative complexities. Given the social, political and technical constraints, it is no wonder that "the procedures for designing water rates have generally been on a trial and error assumption applied to the sales records of the particular community" (American Water Works Association, 1954). Some compromise and inefficiency must be expected but this should not detract from the economic efficiency goal of recovering the total long term cost of providing the last unit of water demanded.

Direct and indirect subsidies of utility systems and energy costs are particularly extensive in the north. Subsidies may facilitate the achievement of public health, social, political, administrative or economic goals but they must be scrutinized to ensure that in attaining these goals they do not induce undue inefficiencies into the utility system. Subsidies that reduce or even eliminate the charge for services tend to distort the demand and this can result in excessive water use, high utility system costs, and the need for further subsidies. Utility system subsidies may include: capital and/or operating grants or loans; installation and/or operation of the utility system; or price subsidies to consumers. Where these subsidies are extensive, the agencies providing the subsidies will be the main beneficiaries of reduced water and energy demands. In other cases, various costs and benefits associated with water conservation are realized by the consumers and the agencies. All agencies that provide subsidies have a responsibility to ensure equity and efficiency within the utility system and cost-effectiveness in the expenditure of public funds. This may be achieved by charging consumers the full economic rate (marginal price) for water consumption that is above a reasonable quantity. In some cases, subsidies for for purchase and installation of water conservation devices may be appropriate, equitable, and more economical than utility system subsidies. Similar national programs have been initiated to assist homeowners and industry to reduce heat loss and energy demand.

2.6 Plumbing Codes

Plumbing codes or guidelines establish minimum standards for the design and quality of materials and the operation and performance of various building plumbing fixtures. Often they are covered within building codes. National codes are available, and can be adopted in whole or in part by a municipality, government agencies, building mortgage funding institutions or other groups. They are usually applied to new construction. Although their intention is commendable, unfortunately, sometimes they can impede water conservation.

Plumbing code provisions often specify flow rates or other characteristics that are based on the existing available level of technology (Milne, 1976). Unfortunately, they may not anticipate innovations and new technology that may be equally adequate or even improve the function and operation of fixtures. The adherence to existing codes is warranted when they protect the consumer; however, non-performance oriented code requirements appear sometimes to be market protection motivated. The dominance of manufacturers on the Canadian Standards Association may be viewed as a conflict of interest by some. A good example of this is the dimensional requirements that to a large part have kept the European low water use toilets out of the North American market (Thureson, 1977). The introduction of new water saving technology or procedures may require plumbing code revisions.

Plumbing codes have also been used to promote water conservation technology and to reduce water demand. Two notable examples of the use of local plumbing codes as part of a water conservation campaign were in Washington and California. A number of examples of local ordinances, regulations and building code provisions are compiled by Nelson (1976). The most common provisions have established a maximum flush volume of 13.25 L (3.5 U.S. gallons) for tank type toilets, and a maximum flow rate of 11.5 or 13.25 L/min (3.0 or 3.5 US gallons per minute) for shower heads and 7.6 or 15.15 L/min (2.0 or 4.0 US gallons per minute) for other faucets. Other provisions have specified the reduction of household pressure to 415 kPa (60 psi), the insulation of piping and/or the circulation of hot water, and various industrial, public facility and outdoor water use restrictions. Some of these plumbing codes have specified appropriate performance criteria while other agencies only allowed the use of approved products which would meet their standards. Some agencies made across the board requirements, while others differentiated between new and existing buildings. In the north, there are fewer examples of effective water conservation plumbing codes. New developments in some areas in Whitehorse, Y.T. must install heat traced service connections that do not require bleeding to prevent freezing. Unfortunately, since a flat rate is charged for water use, many consumers still bleed water rather than operating the heating system (Ellis, 1978). Buildings on the truck system in Yellowknife, N.W.T. must install minimum size water and sewage holding tanks, a rather indirect and inefficient way of reducing costs.

Water conservation plumbing codes can be successfully implemented. It should be pointed out that none of the examples in the literature specified radically new technology or innovations that would in any way alter the consumers perception of a utility system. Generally, existing or water conservation plumbing codes have not promoted the reduction in hot water to reduce energy requirements. Where energy costs are high, this may be justified and initiated similar to building codes that specify minimum insulating values for building walls.

The use of plumbing codes to reduce water demand restricts free choice and individual cost effectiveness analysis. Although most people will comply with reasonable requirements, strict enforcement may be impractical and abuses will occur. Across-the-board installation requirements, particularly for existing buildings, may be challenged by persons who are willing to pay for their high water demands. Philosphically, one might argue that common sense should not and cannot be regulated. However, these considerations only apply if the consumer is paying the full marginal cost for water and sewer service net of any subsidies. This is rarely the case, and the agencies providing subsidies have the right, if not the obligation, to ensure efficiency. Therefore, across-the-board water conservation requirements that are cost effective in terms of the overall local, regional, national and the consumers resources may in fact be more desirable and equitable than allowing free choice. In an emergency situation, the costs and inconvenience that may result from water conservation requirements are justified by their expediency in facilitating reductions in demand and because they ensure that everyone participates for the common good.

Plumbing codes are generally only enforceable during the construction or remodeling of buildings when various agencies must inspect and approve the works. Thus, a change in the plumbing code to require water conservation may take many years before any impact is noticed. This is not to discount the use of plumbing codes since they will have long term results and are easy to administer and since they apply to everyone, they are equitable.

Regardless of the use of plumbing codes to reduce water demand, it appears desirable to revise codes so they at least permit the use of water conservation where they are warranted on the basis of economic, sanitary and other considerations (Chan et al, 1976). Existing standards were developed on the basis of current designs of products, therefore, in many cases, it will be necessary to write new standards (Deibert, 1977).

2.7 Public Acceptance

The demand for water, like any commodity, can be influenced by advertising. A public education campaign can provide knowledge of the reasons and benefits of water conservation as well as an awareness of the methods of reducing water and energy demands. Short and long term modifications of society's attitudes and behaviour related to water use and water conservation technology can be molded by public education and opinion. It may be very difficult to achieve water conservation when the methods prescribed are foreign and not readily acceptable by the users. People do not like to be forced into a behaviour they feel is inappropriate for them (Milne, 1976) and they may resist changes, particularly dictated ones, even before trying them out. A properly instituted water conservation campaign can itself significantly reduce consumption and also increase the application and acceptance of water conservation methods and technology.

Attitudes towards water use and water using appliances are acquired and are therefore dictated by environment and culture. The history of domestic water technology, household plumbing and cultural attitudes that affect water use were reviewed by Milne (1976). The first known water carried toilet systems were constructed by the Sumerians of the Near East in about 3500 B.C. but it was not until 1596 that Sir John Harrington invented the forerunner of the indoor water flushing toilet and not until the 1800's did these became popular. Early versions flowed continuously and used considerable volumes of water. Reyburn (1969) credits the illusive Thomas Crapper with the 1872 invention of the modern water closet with a syphon tank mechanism which is still used today (Love, 1975).

Bathing rituals and the public acceptance and importance of bathing have also varied greatly with different cultures and in different periods. The indoor bathroom with permanent toilet and bathing facilities was not popular until the early 1900's and has since undergone functional and appearance changes (Kira, 1976). The availability of electricity has made possible many new household appliances including the mechanization and automation of laundry washing.

Technological advances, emphasis on mechanization and science, and the increasing cost of labour all contributed to molding the "modern" household plumbing system. New materials and products have increased the real and perceived quality of life. It is tempting in this "age of technology" to attribute this to science however, changing attitudes and requirements of society are equally important in the selective evolution of water technology. The social and technological aspects are tightly interwoven and often it is difficult to say which came first, the product or the demand. It is important to study and philosophize on this issue since water conservation usually requires both a change in technology and attitudes. The North American consumer has been educated to consider water "cheap as dirt" (Murdoch, 1956). A high water use is often perceived as an indicator of high sanitation and quality of life and water conservation, if not approached properly, may be resisted simply to maintain the status quo in fear of a lowering of standards or a return to the much revered "old days".

Effective public education campaigns have been carried out in Washington (Brigham, 1976) and California (Nelson, 1976). The impetus for the Washington campaign was to reduce the flow to overloaded sewage treatment plants. It was deamed a "sewer crisis" and the program to reduce consumption emphasized environmental protection and the escalating water and sewer rates. The real cause, the sewerage system not keeping up with growth, was not prevalent in the public campaign. Among the awareness strategies used were the organization of water saving workshops for managers; slide speaker programs for civic and service organizations; assembly of information on water saving devices; preparation of television and radio announcements and a film; and a continuing public participation campaign including a water saving idea contest. These were followed up with the free distribution of water saving kits which included dye pills for toilet leak detection, plastic bottles for flush water displacement, plastic shower control inserts to reduce the flow to 11.5 L/min., and an instruction and helpful hints booklet. Plumbing code changes were adopted to make water saving fixtures mandatory for new developments. The public education campaign was well received and effective. Similar methods, but with more emphasis on lawn watering and gardening, were utilized in parts of California during their recent two year water shortage. There have also been other local and national public education campagins in North America and other parts of the world. They have generally been in response to a crisis situation, such as a drought resulting in a water shortage, and everyone could see the reasons and the need for conservation. When the crisis ends the unmotivated consumers may revert to old habits and even previously used technology; however, a temporary shortage can make people more aware of the volume of water they waste and education can change wasteful habits (Abbot et al, 1972). For example, the post crisis residential water consumption in Marin County, California is still 45% below pre-drought levels which indicates that their conservation campaign has had some lasting, if not permanent, effects (Consumer Reports, 1978).

A growing number of environmental/conservation oriented individuals, organizations and magazines as well as government and even some resource industries are attempting to modify our attitudes and lifestyle towards a conserver society. The advocates of the compost toilet exemplify this movement within the water and wastes area (Stoner, 1977). The motivation to conserve may be philosophical with the emphasis placed on self-sufficiency, reduction of pollution, recycling of nutrients, or the global conservation of resources. The "converted" may be eager to accept, or at least willing to try, alternatives which require their involvement and attention and perhaps a change in old habits and perceptions. The capital cost, operating requirements or the strictly economic benefits may not be important issues. The self-satisfaction and/or approval of conserving peers may be sufficient to achieve acceptance of water conservation from this group. The activities and examples of such small groups can have a significant influence on the larger society.

The methods used to gain public support and acceptance of water conservation methods and technology include media messages, public speeches, leaflets, public participation and these methods require the support of the utility company, public officials and institutions. Individuals and groups are motivated for different reasons or benefits and it is important to appeal to as many of these as possible. To date, water conservation campaigns have been crisis and/or philosophically motivated. It is not certain what degree of acceptance can be achieved solely by the promise of long term monitary benefits and it appears that other benefits and motivations must also be emphasized to achieve public acceptance of water and energy conservation methods and technology.

2.7.1 New Technology.

The use of new technology to reduce water consumption will meet with opposition by those who reject any innovation simply because it is new. To improve acceptance, new technology must be attractive, convenient and economical. Public acceptance may be increased if new technology resembles or at least doesn't differ radically from existing devices, has an element of gadgetry or toylike quality, and has snob appeal and is prestigious (Milne, 1976). In some cases, a lower water use device will be perceived as a lower standard and it will not be tried.

Schatzberg et al (1975) found that the acceptance of new technology inceased with use. Their survey of naval personnel who had used a protype 2 L/min shower system revealed that 53% of those who had one or two showers would not be willing to use the device at a shore-based facility, but acceptance increased to 77% for those who had used the shower system more than twice.

The purchase and use of new technology is understandably resisted when it is untried or unproven. Therefore, the promoters must demonstrate the application and benefits and publicize the results. Radically new technology, such as recycle, will require much more field demonstration before it is technically feasible as well as socially acceptable.

2.8 Water Conservation Technology

A brief summary of water conservation technology is presented here with a detailed discussion and evaluation presented in Appendices B to G under the topics of: Toilets, Bathing, Laundry, Kitchen, Miscellaneous and Reuse Alternatives. The recent interest in water and energy conservation has spawned many new products and some may have been inadvertently missed. Also, for any particular device there may be many variations and models from numerous manufacturers. The intention of this report is not to produce a definitive list of products but only to provide a representative list of alternatives and products. An unbiased testing program was not specifically carried out, therefore, in many cases the operation and performance data are based on published literature, manufacturers' information and personal experience.

2.8.1 Toilets. Toilets use more water than any other fixture within the home. Conventional toilets, which typically use 20 L/flush, can be easily modified by the homeowner to reduce the water used for flushing by the installation of inexpensive dams or dual flush attachments or by the installation of homemade devices such as weights or plastic bottles. These reduce the water used by approximately 10 to 35% but still permit efficient toilet operation. A more expensive device replaces the gravity reservoir with a small tank which is pressurized by the water system and uses only 10 L/flush. A number of American manufacturers now offer, at a slightly higher cost, shallow trap toilets rated at 13.5 L/flush (3.5 U.S. gallons) but this volume is still higher than the conventional European toilets which use only 6 L or 9 L/flush.

There are a number of low water use toilets available, some of which can not or should not be used with a municipal gravity sewer system. The lowest flush-tank toilet unit is a 3 L toilet manufactured in Sweden but this unit should only be used with a holding or septic tank. An air pressure toilet which uses 2 L/flush can be used with a gravity sewer. The vacuum toilet uses 1.5 L/flush but requires a vacuum collection system. Where horizontal transport is not required, fresh water flushing can be achieved with a mechanical seal 0.5 to 1 L toilet placed directly over the holding tank. The lowest of the water using flush toilets are the recirculating variety which require an initial charge of water and chemicals or other additives and use an average of 0.2 L/flush.

There are also a number of toilet alternatives that do not require any water. Freezing and packing toilets are convenient and more sanitary versions of the indoor bucket toilet. A few systems use a recirculated synthetic fluid to transport waste to a holding tank. Incinerating toilets have only a small quantity of ash to remove but use considerable energy. Compost toilets rely on aerobic decomposition of wastes and evaporation of moisture to reduce the volume. Large compost toilet models use natural convection and self-generated heat while compact units usually have an electric fan and heater and a mechancial mixing device.

It is important to note that not all of these toilet alternatives are applicable or appropriate to every situation. For example, a mechanical seal toilet must be located directly over a receiving tank; a 3 L flush toilet should only discharge to a tank less than 25 m away through a sewer line with a minimum slope of 3%; but a recirculating toilet could discharge into a gravity sewer system. Other alternatives, including some reuse systems, are beyond the operating capabilities of individuals and present severe maintenance difficulties, particularly when located in isolated communities.

2.8.2 Bathing. Depending on the habits of the user, showering usually requires less water than tub bathing, particularly if a flow restricting insert or a low flow showerhead is installed. These devices reduce water flow to about 1/3 to 1/2 that of a conventional shower-head which delivers 15 to 40 L/min. Many of the units give a satisfactory or even superior shower while saving considerable water and energy required for hot water heating. With a hand-held shower unit which has a spring loaded on/off switch, a wet-soap-and-rinse shower can be taken with only 10 L of water. An air assisted shower system is considerably more expensive and difficult to install but provides an acceptable shower at a water flow rate of only 2 L/min. An atomizer nozzel may provide body cleansing with as little as 1 L per use but it will take longer than a conventional shower and may not be satisfactory to many people.

Thermostatic or pressure compensating mixing valves are available to maintain a constant shower water temperature and thus provide a more convenient shower and at the same time reduce waste.

2.8.3 Laundry. Hand laundry can potentially use the least amount of water but requires considerable user time and energy. With wringer washers the reuse of the water is facilitated but wringer washers have largely been superceded by the more convenient automatic washing machines. There are numerous top loading automatic washers available, some of which use considerably more water than others. The more efficient tumble action of the front load automatic washer makes possible a 38% reduction in total water use and a 53% reduction in hot water use compared to the average top loader. Front load washers are more expensive and to date they have not been well received by consumers.

2.8.4 Kitchen. Within the kitchen, dishwashing uses the most water. Dishwashing by hand can be done with very little water and the volume can be varied depending on the number of dishes. If only full loads are done in an automatic dishwasher, the water used will be comparable to hand washing in a filled sink bowl and rinsing under a free flowing stream of water. The in-sink food waste disposal unit is another modern convenience that, if judiciously used, will not significantly increase household water use. Other kitchen water use operations, such as drinking and cooking, use relatively fixed volumes of water. Reductions in waste can be achieved by adjusting user habits and through simple means such as by keeping a container of cold water in the refrigerator.

2.8.5 Miscellaneous. There are a number of faucets and faucet attachments that reduce the water flow and waste compared to conventional faucets. Inexpensive flow limiting inserts can reduce the flow rate by as much as 75% and aerators create the illusion of a full flow while actually cutting it in half. Both of these features are incorporated into an inexpensive, easily installed faucet attachement. A single faucet with one control handle for adjusting both the flow rate and temperature can reduce the wasting of water during temperature adjustments. A special single faucet is available which produces a spray with only about 10% of the flow rate of a conventional faucet but is adequate for hand washing. Spring loaded and self-closing faucets also reduce waste since they must be attended in order to operate. Thermostatically controlled mixing valves can be used to maintain a constant pre-selected water temperature.

A pressure reduction valve can be installed where the watermain pressure is excessive. This will reduce leakage and the maximum flow rate and thus water use is reduced.

Insulation of hot water lines reduces the rate of cooling of hot water pipes. This reduces the need to waste the cooled water in the hot water line between the faucet and the hot water heater when hot water is desired. Wasting of cooled water can also be eliminated by looping the hot water pipes and circulating hot water through them. Alternatively, buildings on truck systems need only provide a valved drain line back to the water cistern so that the drained water is saved. This warm water should not appreciably increase the temperature of the water cistern.

Wastewater can be treated and recycled, thus reducing fresh water requirements. The simplest systems recycle greywater only for toilet flushing. Increasingly more complex systems recycle greywater for laundry and/or showers. The most sophisticated systems may recycle all wastewater for all uses and have negligible water requirements and environmental impact. Wastewater reuse is generally less economical or attractive compared to non-reuse water conservation alternatives and complex reuse systems are beyond the operating capabilities of most individuals, particularly when located in isolated communities.

2.9 Economic Analysis

Most reports on water conservation have included some mention of economics; however, few detailed economic analyses have been performed. One of the earliest investigations by Bailey *et al* (1969) showed that, for a family of four, a variety of devices were economical. Wenk (1971) further refined this work for three water rates and several soil types for septic systems. Howe and Vaughn (1972) found that cost incentives for water-saving devices were not great; however, the authors neglected the energy savings due to reduced hot water requirements. The Environmental Protection Agency (1974) in its report to Congress presented an appendix with typical cost-effectiveness analyses. The most detailed economic analysis was conducted by Chan *et al* (1976). They derived a computer model which used cost functions for the water and wastewater utility systems in conjunction with a water demand function for household water use to estimate the overall reduction in water demand and costs due to the use of various water conservation devices. Cost and water demand characteristics for various regions in the USA for typical communities of 50,000 were used to estimate the total national savings through the use of: faucet aerators, thermostatic mixing valves, flow-limiting shower heads, dual cycle toilets, shallow trap toilets, vacuum toilets, toilet inserts, and greywater recycle to toilets. They found that high water rates of $2.64/1000 L rendered all devices economical, even for the immediate replacement case.

Economic studies in the literature have usually been based on a typical household which is connected to a municipal piped utility system and the rates used for water, sewer and energy were typical of southern conditions. Therefore, many alternatives which were found to be uneconomical may be more attractive in the north where costs are higher.

It is important to note that the lowest cost alternative is not necessarily the "best" choice, rather it is simply the lowest cost given the assumptions in the analysis. Intangibles such as social desirability, aesthetics, user preference and convenience, applicability of technology, and numerous other pros and cons associated with each alternative are left out of the analysis in order to provide an unbiased economic analysis. These other factors can then be subjectively considered in conjunction with the strict economics to decide a course of action.

Some water conservation devices or alternatives can not be used in certain situations or installation may be impractical in a particular building. The capital and installation costs as well as the operating requirements that are used in the analysis are for normal conditions but each application and installation will be different, particularly when modifying an existing building. Because of the many assumptions, all alternatives within a reasonable range of the lowest cost alternative should be seriously considered. It should be kept in mind that when costs are close, the choice is not critical. In such cases, other factors such as the capital outlay required to achieve the benefits; the disruption of the building and occupants, particularly for retrofit; and other intangibles become dominant. The selection of an alternative with a higher cost must be adequately justified on non-economic grounds. The economic results of any analysis, including this study, serve only to illustrate the procedure and present results for typical conditions. A site-specific economic study will be necessary whenever costs for any of the viable alternatives are appreciably different.

2.9.1 Economic Strategies and Conditions. There are numerous situations in which it is desirable to evaluate the economics of water conservation. These situations may be related to the type of building and users, the type of installation, and the unit cost of water, sewer and energy.

Most of the water conservation studies in the literature are concerned with residential situations and most of these only consider a typical household. For various sized households or non-residential buildings such as schools, hotels, stores and laundromats, the fixtures will receive a different number of uses and this makes it incorrect to utilize recommendations with respect to water conservation based on other situations. Higher usage favours the alternatives which have lower operating costs. For example, a particular toilet may only be cost effective for a large family because it is used more times per year and a front load laundry machine may be much more economically attractive to the operator of a commercial laundromat. Wherever practical, the economic analysis should be related to the number of uses per year so that the results can be applied to various demand situations.

There are three opportunities for installing water saving devices and these lead to three economic evaluation cases. They are:

Case 1 - Installation of a water-saving device or system in a newly constructed building.

Case 2 - Immediate replacement of a conventional fixture with a water-saving device. Only operating costs for the existing device or system are considered whereas the retrofit device or system also incurs a capital and installation cost. Any removal cost and salvage value of the existing system should also be considered but the original cost of the existing device is not considered.

Case 3 - Installation of a new device when the existing device or system requires replacement, perhaps due to failure or aesthetics. All alternatives, including replacement with the original conventional device, incur capital and operating costs. Any removal cost and salvage value are common and can be neglected.

For the new water-saving devices, Case 2 is economically the same as Case 3 if the removal cost is counter balanced by the salvage value of the existing device. With Case 2 the continued use of the existing system does not incur any capital cost, therefore, this is the least attractive opportunity for the installation of a water conservation alternative. Conversely, if a device is economical for Case 2 then it is economical for all the other cases. Case 1 and 3 are basically the same except for alternatives or devices that have a higher installation cost when retrofit than for new installations. For example, it may be much more expensive to retrofit an air pressure assist shower system into an existing bathroom than if it were installed into a new building, whereas the installation cost of a low flow showerhead is usually the same for both retrofit and new installations. Often installations are somewhat governed by their practicality. For these reasons Case 3 can be neglected. Chan et al (1976) put the emphasis on Case 2, immediate replacement, since with Case 1 only new housing stock is influenced and because this is a small fraction of the total buildings it would take many years to significantly influence the overall community water demand.

The economics of a water conservation strategy is dependent on the unit costs for water and sewer and for energy since these determine the operating costs of the alternatives. The model developed by Chan et al (1976) which calculates the total cost for water and sewer service at various consumptions is the precise approach to assessing water conservation but a more practical and commonly used method is to utilize specific unit costs. The unit cost used should be the total marginal unit cost, net of any subsidies, although in most cases this is not available. The unit costs are different for every utility system and there is a wide range of values, therefore, it would be impossible to select an average condition. For fixtures or devices that do not use energy or hot water, such as a flush toilet, it is possible to calculate and plot the operating costs for all unit water prices but when another variable, say energy cost, is introduced it is necessary to select specific unit cost values to illustrate cost effectiveness. Therefore, a number of "typical" conditions have been selected which cover a practical range of unit costs. Because of the large difference between unit costs for piped and trucked systems, a low and a high condition were selected for each of these systems. They are:

Condition 1 - Piped water and sewer at $0.10/1000 L
 - Electricity at $0.05/kW·h
Condition 2 - Piped water and sewer at $2.00/1000 L
 - Electricity at $0.20/kW·h
Condition 3 - Trucked water and sewer at $10.00/1000 L
 - Electricity at $0.05/kW·h
Condition 4 - Trucked water and sewer at $20.00/1000 L
 - Electricity at $0.20 kW·h

2.9.2 Economic Analysis Procedure. The objective of an economic analysis is to determine the lowest cost strategy. With respect to this study it is not only to determine if a device is economical but to decide which of a number of alternative devices is the most cost effective. There are many economic analysis techniques in use and these are covered in many textbooks, for example, Grant and Ireson (1970) and Jelen (1970). The most appropriate procedure for this situation is the present value analysis (Janssen, 1978). Benefits and costs are not considered separately, rather all capital and operating costs associated with an alternative are discounted to their present value. The alternative with the lowest present value is the most economically attractive.

Since money has a time value, the discount rate is used to convert future costs to an equivalent present value in order to equitably compare alternatives. For the private sector, the discount rate is simply the interest rate that is charged for borrowing money, whether or not it is actually borrowed. For government it is more complex. Generally, the discount rate should reflect the marginal return that investments in the private sector of the economy would yield. Treasury Board Secretariat (1976) encourage that analyses be carried out over a range of values. They suggest the use of 10% discount rate along with calculations of 5% and 15% to indicate sensitivity of results to a change in the assumed discount rate. Because resource requirements are not changed, no allowance should be made for anticipated inflation, or deflation, when it is part of general price level changes. If anticipated price changes in one area, such as energy, are different than general price changes, then the difference can be considered.

Various alternatives should be considered over a common life expectancy. In many cases the life of a device is unknown and the best estimate is used. Future costs are discounted to present value, and distant future costs become less significant at higher discount rates. For example, at a 10% discount rate the present value of a constant annual cost for 10 years is only 28% less than if it lasted for 20 years. Also, many fixtures are replaced before they actually fail and distant future costs are more uncertain. For these reasons an economic life of only 10 years is generally used in the economic analysis. Often only rough estimates of capital or operating costs as well as water and energy requirements are available. In such cases a reasonable range of values can be tried to see how this influences the economic selection between alternatives. This also indicates where refinements in operating data or costs are necessary in order to make a decision.

A sensitivity analysis should be carried out when there is uncertainty with the discount rate, economic life, capital and installation costs, and operating requirements. In some cases the range of values for a particular parameter within which an alternative is economically attractive can be defined.

2.9.3. Present Value Equations. General equations to calculate the Present Value of an alternative for the various economic cases can be formulated.

Case 1 = New Installation

Present Value = Initial Cost of Device + Present Value of Annual Operating Cost of Device During its Economic Life

Where:

Initial Cost = Capital Cost + Installation Cost

Annual Operating Cost = Annual Water and Sewer Cost + Annual Energy Cost for Hot Water + Annual Operating Costs for the Device (energy, chemicals, etc.) + Annual Maintenance Cost for the Device (repairs, labour, etc.)

Annual Water & Sewer Cost = Volume of Water Used X Unit Cost of Water and Sewer

Annual Energy Cost for Hot Water = Volume of Hot Water Used X Temperature Difference Between Hot and Cold Water X Energy Conversion Factor X Unit Cost of Energy

If the temperature difference between hot and cold water is 50°C, the Energy Conversion Factors per litre of water per °C are:

Electricity (kW·h) = 1.163×10^{-3} kW·h/L·°C at 100% efficiency (normal)

Oil (L) = 1.083×10^{-4} L/L·°C at 100% efficiency

= 1.353×10^{-4} L/L·°C at 80% efficiency (normal)

Natural Gas (m^3) = 1.091×10^{-4} m^3/L·°C at 100% efficiency

= 1.364×10^{-4} m^3/L·°C at 80% efficiency (normal)

The Present Value of the Annual Operating Costs is calculated from:

Present Value = Present Value Factor X Annual Operating Cost

Present Value Factor = $\frac{(1 + DR)^{EL} - 1}{DR\ (1+DR)^{EL}}$ or from tables in economic textbooks.

Where:

DR = Discount Rate (%/100)

EL = Life expectancy or economic life of the device

Case 2 = Immediate Retrofit

Present Value = Initial Cost of Device + Removal Cost of Existing Device - Salvage Value of Existing Device + Present Value of Annual Operating Cost of Device During its Economic Life.

For Case 2, the Installation Cost will be that required for a retrofit installation. The Present Value of retaining the existing device is only the Present Value of its associated Annual Operating Costs.

3 SUMMARY AND RECOMMENDATIONS

3.1 Pricing Policy

Water demand is dependent upon many factors including the type of utility system, building plumbing, climate, family size, socio-economic status, and price. This latter factor is significant to utility system operators because it can be manipulated to adjust the demand to obtain an overall least cost water and sewer utility service. Metering of water use and a charge to consumers based on water use are essential to water demand and utility system management. With the notable exception of a flat rate, any unit price scheme can equitably return adequate revenue while facilitating water conservation and encouraging efficiency, providing the unit price reflects the actual cost for that service. As a goal, the pricing scheme should follow the particular long term marginal cost function for the utility system. For piped systems, this is typically assumed to be a decreasing unit price because of the "economy of scale" and minimum sizes for systems with fire protection; however, many utility operators find that providing for a high capacity involves substantial expenditures and unit costs will not always decline with expansion. For trucked systems, the unit price for water delivery and sewage pumpout is relatively constant since most of the costs, such as labour, vary directly with demand and fixed costs are less significant. Unfortunately, it is impractical to determine the precise long term marginal cost function for a particular utility system or consumer. Also, administrative practicalities or goals and subsidies will distort or even dictate the pricing scheme and in some instances, even the price. For example, in heavily subsidized systems and in small communities it is tempting to reduce the complexity of administration by charging a flat rate. Some inefficiency must be expected but this should not detract from the economic efficiency goal of recovering the total long term cost of providing the last unit of water demanded.

Subsidies to water and sewage services may facilitate the achievement of public health, social, political, administrative or economic goals. They must be scrutinized to ensure that, in attaining these goals, they do not induce undue inefficiencies into the utility system. Subsidies tend to distort the demand which can result in excessive water use and high utility system costs, and in some cases the need for further subsidies. Utility system subsidies can take many forms including: capital and/or operating grants; installation and/or operation directly by government; or price subsidies to consumers. Where these subsidies are extensive, as in many northern locations, the agency rather than the consumer may be the main beneficiary of a water conservation program. In other cases, various costs and benefits associated with water conservation are realized by the consumer and the subsidizing agency. All agencies that provide subsidies have a responsibility to ensure equity and efficiency within the utility system. This may be achieved by charging consumers the full economic rate (marginal price) for water consumption that is above a reasonable quantity. In some cases, subsidies for the purchase and installation of water conservation devices may be appropriate, equitable and efficient. Similar national programs have been initiated to assist homeowners and industry to reduce heat loss and energy demand.

3.2 Plumbing Codes

Plumbing codes and guidelines are usually established to protect the safety and health of the user and establish minimum standards for materials and operation. However, they should also encourage efficiency and not unnecessarily impede water conservation, as some existing standards do. A notable example of this is the discrimination against the use of European toilets. This must be rectified.

There is a need to formulate a general guideline for both piped and trucked systems that emphasizes water conservation. All or portions of it could then be easily adopted by interested government agencies, municipalities or others responsible for building design or utility systems. It may include recommended maximum values for water pressure, flow rate at fixtures including showers, and water use for toilet flushing and laundry. The guideline may also require the insulation of hot water lines, circulation or return system for hot water, the installation of water meters, and other devices. It may also include special options for public facilities, lawn watering, reuse, and stringent requirements that could be adopted where there is a water shortage or where water and sewage service is very expensive.

3.3 Water Conservation Strategies

It must be emphasized that the cultural attitudes and the personal bias of the users have to be considered when encouraging or implementing water conservation. Utility operators or agencies supplying subsidies that are interested in reducing water use should initiate a public information and education campaign that involves the consumers. Changes in wasteful attitudes and behavioral practices combined with knowledge of simple water conservation hints and an awareness of the benefits of water conservation can in themselves reduce total water demand. Water conservation devices can further reduce waste and conveniently increase the efficiency of water use.

Familiarity with water conservation methods and devices will improve their acceptance and increase their application. This is particularly true for new technology and foreign devices that may be rejected without trial even when they provide an adequate or even superior level of service or convenience. Unproven technology must be fully tested and demonstrated before acceptance and general application can proceed.

Consumers and utility agencies must also be made aware of the strict economics of various functionally adequate water conservation alternatives. In this way they can assess the economic benefits and compare these to any real or perceived inconvenience or lower quality of service. This report outlines the technical and cost data for various alternatives in order to calculate the total present value of the initial capital and installation costs as well as the operating costs. Intangible benefits such as autonomy, conservation of resources, and reduced pollution and other influencing factors such as preferences, aesthetics and quality of service are excluded from the strictly economic analysis.

There are practical and technical limitations to a comparison and economic selection among alternatives. For simplicity, in this report the total costs for the alternatives are based on fixed unit costs for water and sewage service and for energy. A more precise but very complex analysis would be based upon the total system and household costs, particularly when there is a large reduction in water demand made possible by the concurrent use of a number of water conservation devices. Also, in this report the total costs and benefits are included as if one agency or the consumer were paying for the total capital and operating costs. Where the consumer or one agency does not pay the total costs, perhaps due to subsidies, it is left up to the administrators to sort out the costs and benefits and possibly, though reluctantly, deviate from the recommended optimum economic strategy.

In order to illustrate the economic selection methodology and typical results, an analysis for a typical household of four persons with full plumbing is presented in the Appendices. There are many inherent assumptions necessary and in practice there is no typical household; therefore, where conditions are significantly different, a site-specific analysis should be carried out. To increase the applicability of these results, the analysis was carried out for each water using household function at low and high rates for water and sewage service and electrical hot water heating for both piped and trucked systems. Two cases, retrofit and a new installation, are considered. The results of these analyses and recommendations are highlighted below and summarized in Table 3. The reductions in water and energy use that are indicated in Table 3 are based on a typical household water consumption for a family of four, which would be approximately 900 L/d for houses on a piped system and 380 L/d for houses on a trucked system.

3.3.1 Piped Systems. The economic analysis for the retrofit case indicates that conventional toilets should be modified by the installation of a dual flush mechanism or a dam insert to reduce the volume of water used per flush. A low flow shower head with integral on/off value should be installed and to complement it a hand-held shower unit may also be installed. All faucets should have a flow control aerator added onto the spigot. Where the water main pressure is excessive, a pressure reducer should be installed and, wherever practical, the exposed hot water pipes should be insulated. These toilet, shower and faucet modification recommendations would have a capital cost of approximately $25 and can easily be installed by the homeowner and would reduce total household water demand by 28% to 38%. The high value would be realized where only showers rather than tub baths are used. The total annual savings per household would be $80. to $120. at the low rates and $480. to $700. at high rates, most of which is due to reduced energy use.

TABLE 3. RECOMMENDED HOUSEHOLD WATER CONSERVATION STRATEGIES

● Recommended
↓
○ Preferred option

	Piped systems		Trucked systems	
	Retrofit installation	New installation	Retrofit installation	New installation
Toilet				
Dual flush or dam	●			
15 L or less per flush		●		
3 L or less per flush			●	●
Bathing				
Low flow shower head	●	●	●	●
Hand-held shower unit	○	○	○	◑
Temperature control valve				◑
Laundry				
Front load washer		○	◑	●
Miscellaneous				
Flow control aerator	●	●	●	●
Mixing faucet		◑	○	●
Temperature control valve				○
Pressure reducer	○	○		
Insulate hot water pipes	○	●	○	●
Circulating or return hot water				◑
Savings over conventional[(1)]				
Water (%)	28-38	31-55	50-67	60-74
Water (L/person·d)	63-84	70-124	47-63	57-70
Energy(2) (kW·h/person·d)	1.34-2.03	1.56-2.26	0.56-1.69	0.86-1.16

(1) Range of values depends on alternatives or devices used and bathing habits.

(2) For household hot water heating.

For a new building or where an existing fixture is to be replaced, it is recommended that the toilet be one that uses 15 L or less per flush. A conventional toilet with one of the simple modifications is recommended at low water rates whereas at higher rates the European 6 L toilet is the most economically attractive alternative. A low flow shower head is very economical and an on/off switch and a hand-held shower unit are desirable optional equipment. Flow control aerators should be installed and when mixing faucets are not too expensive, their convenience and reduced water use make them desirable. Insulating the hot water pipes also improves convenience and is usually economical for a new building. Where the water main pressure is excessive, a pressure reducer should be installed. These recommendations would entail an incremental capital cost over and above that of conventional plumbing fixture costs of approximately \$25 to \$115. depending upon the toilet selection. Household water use would then be reduced by 31% to 55%. The higher cost and reduction values pertain to the use of the European 6 L toilet and where only shower bathing is used. The total annual savings per household over conventional plumbing fixtures would be \$125. to \$185. at the low rates and \$550. to \$850. at the high rates.

3.3.2 Trucked Systems. Because of the high unit cost of water for trucked systems, the strategy outlined in Table 3 for the retrofit case recommends the removal of conventional toilets and installing a unit that uses a maximum of 3 L per flush. Where a mechanical seal toilet can not be installed, the most economical alternative is a recirculating toilet. The only conventional flush type toilet that should be considered is the European 3 L toilet. Tub-bathing is very expensive compared to showering. A low-flow shower head should be installed and the installation and use of an on/off switch and a self-closing hand-held shower unit should be encouraged. Where utility rates are high and/or there are a large number of wash loads, retrofitting with a low water use front load automatic washer will be economical. Mixing valves are a desirable option but in any case flow control aerators should be installed. Where practical, hot water pipes should be insulated. The cost of these recommendations will vary with the options selected. If all of the options including a front load clothes washer are installed, the capital cost would be $1,000. and the total water demand would be reduced by approximately 50% to 67%. The total annual savings per household over conventional plumbing fixtures would be $750. to $1000 at the low rates and $1500. to $2300. at the high rates. Without changing the laundry machine, the capital cost would be approximatley $300. and the benefit would be a 48% to 53% reduction in total water use.

For a new installation even more drastic changes from conventional plumbing fixtures are economical. The toilet selected should use 3 L or less per flush and the toilet alternatives in order of increasing economic attractiveness are the European 3 L, the recirculating and the mechanical seal toilet. A low-flow shower head and a self-closing hand-held shower unit should be used and a temperature control valve can be installed to increase user convenience and reduce waste. A front load clothes washer becomes quite attractive, particularly where there are a large number of wash loads per week. Mixing faucets with flow control aerators should be installed. Hot water pipes should be insulated and in most cases a hot water circulation or return system would economically increase user convenience. The incremental capital cost of these items above conventional plumbing costs would be $325. to $525. If the frequency of use and personal habits are unchanged, the installation of these devices would provide a reduction in trucked household water use by 60% to 74% and water requirements would be reduced to 38 to 25 L/person·d. The total annual savings per household over conventional plumbing fixtures would be $900. to $1100. at the low rates and $1900. to $2400. at the high rates.

One of the assumptions made for trucked households was that the household water use distribution was similar to that for piped systems (Table 2, Figure 3), even though the total water use is typically much lower than for piped houses. The same percent reduction in water use for each function was then applied to the trucked and piped systems. A more conservative estimate of the benefits of water conversation devices would be to assume the fixture usage rates obtained from piped household data. Typical daily per person rates would be approximately 4.5 toilet flushes, 0.43 baths and 0.17 launderings. If a recirculating toilet (0.2 L/flush), low-flow shower head (45 L/bath), front load automatic clothes washer (119 L/load), and other miscellaneous devices were installed the total water use would be approximately 50 L/person·d. This value represents the lower limit of water demand in a house equipped with cost-effective water conservation plumbing fixtures and no conscious effort on the part of the householders to conserve water. This 47% reduction in water demand represents a total annual savings per household over conventional plumbing fixtures of approximately $650 at the low rates and $1300. at the high rates.

3.3.3 Public Buildings. For most public buildings such as schools, offices, hotels or laundraumats, the uses per fixture will be higher than for a household; therefore, the recommendations in Table 3 would apply as a minimum. In addition to household options, self-closing faucets and low flow showers with timers should be installed. Spray faucets for lavatories should also be considered, particularly where utility costs are high. Temperature control valves that control a number of faucets and a circulating hot water system are desirable and may be necessary with some faucets.

3.3.4 Critical Situations. Where utility costs are very high and/or where there is a limited water supply, severe steps may be necessary to reduce water requirements. The inherent lower water use and greater control available with a trucked system will probably rule out a conventional piped system, and perhaps even a non-gravity sewage collection system. Even in this situation household reuse is not attractive when compared to water conservation. Households should use a mechanical seal or recirculating toilet. A self-closing hand-held shower unit is recommended for bathing; therefore, a hot water circulation or return system and a temperature control value will be necessary. A spray faucet could be installed in the lavatory and other locations should use mixing faucets equipped with flow control aerators. Along with a front load clothes washer, these fixtures could reduce trucked household water demand by 78% which would be only 21 L/person·d compared to a normal trucked household demand of 95 L/person·d.

If a central laundry were used, the household demand would be reduced to only 13 L/person·d. In some cases a central laundry with reuse may be economical but due to the rather complex treatment technology that is necessary this should be approached with some caution.

3.4 Further Studies

Within this report a number of assumptions that have been made should be verified. In particular, the characteristics of water use within northern households served by piped and trucked systems should be monitored. This should be carried out on houses equipped with full plumbing that are occupied by native and whites of various occupations.

The water conservation recommendations in this report should be demonstrated in both retrofit and new installation situations for both piped and trucked systems. The objective would be to survey user acceptability and to determine the economics. Individual fixtures may be tested but houses completely equipped with water conservation technology should be demonstrated. Two categories of water conservation technology should be demonstrated and assessed. The first category consists of known and available technology such as the low flow shower head, flow control aerator, conventional toilet modifications, and recirculating and European toilets. A second category of new or undeveloped technology should be demonstrated in more selective and controlled situations. This would include the self-closing hand-held shower unit, return hot water system and reuse at a central laundry.

The continued monitoring and development of water conservation technology to further increase user convenience and acceptance and to reduce capital and operating requirements should be encouraged and funded. Areas in which future technology could provide benefits include the development of very low or even non-water using dishwashing and laundry alternatives; simple greywater reuse systems for households and central laundry; and a reliable, aesthetic and compact compost toilet that does not require supplemental heating.

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TABLE 4. CONVERSION FACTORS

SI Units	SI Symbol	Conversion Factor	
Centimetre	cm	x 0.3937	= Inch
		x 0.03281	= Foot
		x 0.01093	= Yard
Cubic Centimeter	cm^3	x 0.06102	= Cubic inch
		x 3.5314 x 10^{-5}	= Cubic foot
		x 1.3079 x 10^{-6}	= Cubic yard
Cubic meter	m^3	x 6.1023 x 10^4	= Cubic inches
		x 35.3144	= Cubic feet
		x 1.3079	= Cubic yards
Day	d	x 24	= Hours
		x 1440	= Minutes
		x 0.1428	= Week
Degree Celsius	°C	(1.8x°C)+32	= Degree Fahrenheit
Dollars per 1000 litres	$/1000 L	x 28.316	= Dollars per cubic foot
		x 4.5459	= Dollars per gallon (Imperial)
		x 3.7854	= Dollars per gallon (U.S.)
Gram	g	x 0.03527	= Ounce
		x 2.2046 x 10^{-3}	= Pound
Hour	h	x 0.0417	= Day
		x 60	= Minutes
		x 0.00596	= Week
Joule	J	x 9.480 x 10^{-4}	= Btu (mean)
		x 0.2388	= Gram-calorie (mean)
		x 2.778 x 10^{-7}	= Killowatt hour
Kilogram	kg	x 35.2739	= Ounces
		x 2.2046	= Pounds
Kilojoule per cubic meter	kJ/m^3	x 0.02684	= Btu per cubic foot
		x 7.8657 x 10^{-6}	= Killowatt hours per cubic foot
Kilowatt hour	kW·h	x 3413	= Btu (mean)
		x 8.6 x 10^5	= Gram-claories
		x 3.6 x 10^6	= Joules
Killowatt hour per cubic meter	$kW{\cdot}h/m^3$	x 96.645	= Btu per cubic foot
Litre	L	x 0.03532	= Cubic foot
		x 0.21998	= Gallon (Imperial)
		x 0.26417	= Gallon (U.S.)
Litre per day	L/d	x 2.45278 x 10^{-5}	= Cubic foot per minute
		x 1.52764 x 10^{-4}	= Gallon per minute (Imperial)
		x 1.83451 x 10^{-4}	= Gallon per minute (U.S.)
Litre per household day	L/household·d	x 2.45278 x 10^{-5}	= Cubic foot per household minute
Litre per minute	L/min	x 5.885 x 10^{-4}	= Cubic foot per second
		x 3.66 x 10^{-3}	= Gallon per second (Imperial)
		x 4.403 x 10^{-3}	= Gallon per second (U.S.)
Litre per person day	L/person·d	x 0.03532	= Cubic foot per capita day
		x 0.21998	= Gallon per capita day (Imperial)
		x 0.26417	= Gallon per capita day (U.S.)
Litre per person year	L/person·a	x 9.6767 x 10^{-5}	= Cubic foot per capita day
Litre per year	L/a	x 9.67671 x 10^{-5}	= Cubic foot per day
		x 6.02685 x 10^{-4}	= Gallon per day (Imperial)
		x 7.23753 x 10^{-4}	= Gallon per day (U.S.)
Metre	m	x 39.37	= Inches
		x 3.2808	= feet
		x 1.0936	= yards
Millilitre	mL	x 0.03519	= Ounces (fluid, Imperial)
		x 0.03382	= Ounce (fluid, U.S.)
Millimetre	mm	x 0.03937	= Inch
Minute	min	x 6.944 x 10^{-4}	= Day
		x 0.01666	= Hour
		x 60	= Seconds
Pascal	Pa	x 4.0146 x 10^{-3}	= Inch of water (conventional)
		x 2.0885 x 10^{-2}	= Pound-force per square foot
		x 0.145	= Pound-force per square inch
Second	s	x 1.1574 x 10^{-5}	= Day
		x 2.7778 x 10^{-4}	= Hour
		x 0.01666	= Minute
Watt	W	x 0.0569	= Btu (mean) per minute
		x 44.254	= Foot-pounds per minute
Year	a	x 365	= Days (civil)

APPENDIX A

RATE STRUCTURES AND PRICING POLICY

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A. RATE STRUCTURES AND PRICING POLICY

A.1 Water and Sewer Rate Structures

There have been a number of water and sewer pricing schemes that have been used or proposed. They include flat rate, uniform rates, declining block, increasing block, demand rates and peak load rates. The unit price and the total cost to the consumer versus the quantity of water used is illustrated in Figure A-1 (a, b, c and d) for various price schemes. Each has characteristics which make it advantageous and appropriate for various conditions and objectives and each influences water use and conservation differently. A summary assessment of these is presented in Table A-1 from Chan et al (1976).

TABLE A-1. COMPARISON OF VARIOUS RATE STRUCTURES (Chan, et al 1976)

	Revenue Adequacy	Water Conservation	Administrative Simplicity	Distribution Effects	Efficiency
Flate Rate	poor	poor	good	poor	poor
Decreasing Block Rate	fair	poor	fair	fair	fair
Constant Unit Price	good	fair	fair	fair	good
Increasing Block Rate	fair	good	fair	fair	good
Seasonal Rates	good	good	fair	good	good
Hourly Peak Rates	good	good	poor	good	good

Chan et al (1976) constructed a computer model to evaluate the various rate schemes. By utilizing the demand curves from Howe and Linaweaver (1967), and maintaining approximately the same annual cost to the consumer and sufficient revenue to the utility company to construct and operate the system they were able to isolate and quantify the influence of rate structure on various criteria including water conservation effectiveness. The results summarized in Table A-2 indicate the water demands relative to the flat rate alternative for three levels of price

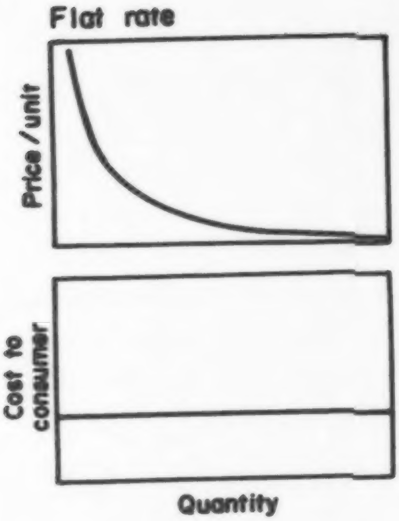

FIGURE A-1(a).

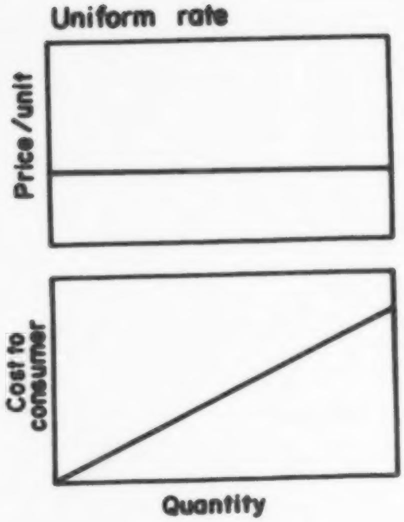

FIGURE A-1(b).

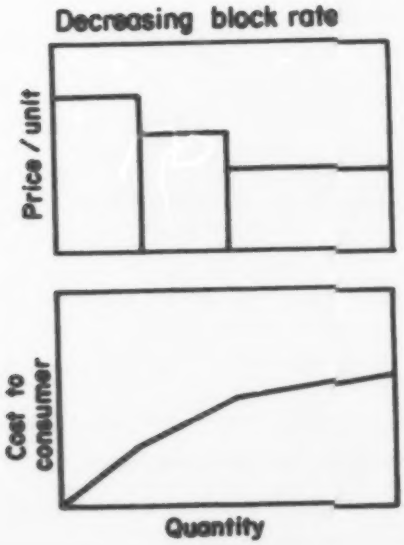

FIGURE A-1(c).

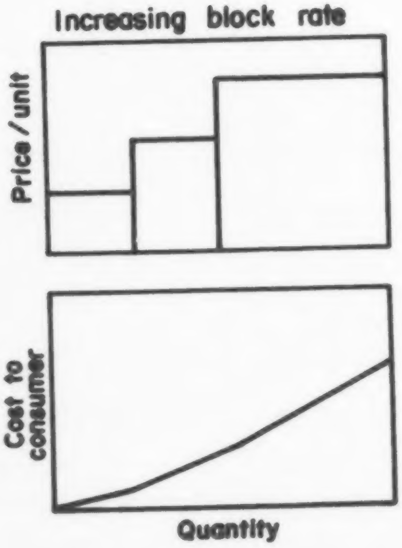

FIGURE A-1(d).

FIGURE A-1(a,b,c & d). WATER PRICE RATE STRUCTURES for utility systems with decreasing, increasing and average cost functions. The cost of the last unit of demand, the marginal price, is also indicated. It can be seen that for a typical household all of the unity price rate structures have lower demands than the flat rate and at the low, medium and high rates the demand is progressively lower. At each price level the unit price rate structures have different demands. For example, at the medium rate the increasing, uniform and decreasing rates have demands of 44%, 48% and 54% of the flat rate demand which is 2120 L/d. However, at the same marginal price the demand is the same, regardless of the rate structure. That is to say, the rate structure itself is only significant to the extent that it establishes the marginal price. This is shown for utility systems with decreasing and increasing cost functions.

TABLE A-2. WATER DEMAND FOR VARIOUS RATE STRUCTURES (Chan, et al, 1976)

Price Level	Increasing Block Rate	Uniform Rate	Decreasing Block Rate	Flat Rate	
	% of flat rate (marginal price)	% of flat rate (marginal price)	% of flat rate (marginal price)	% (rate)	Litres/day·household
Decreasing Average Cost Function					
Low Rate (1)	60% ($0.09/1000 L)	63% ($0.08/1000 L)	67% ($0.06/1000 L)	100% ($3.00/month)	2120
Medium Rate	44% ($0.18/1000 L)	48% ($0.16/1000 L)	54% ($0.12/1000 L)	100% ($6.00/month)	2120
High Rate (2)	33% ($0.27/1000 L)	38% ($0.24/1000 L)	45% ($0.18/1000 L)	100% ($9.00/month)	2120
Increasing Average Cost Function					
Low Rate (1)	65%	68%	74%	100%	1800
Medium Rate	49%	52%	59%	100%	1800
High Rate (2)	37%	42%	50%	100%	1800

(1) 50% of Medium Rate

(2) 150% of Medium Rate

It is apparent that consumption can therefore be manipulated with any of the unit cost rate structures by adjusting the price. Because of the many assumptions in this model, these results should be interpreted with some caution. Also, various rates may be more appropriate and effective in different situations regardless of the total revenue collected. For example, if there is a limited quantity of water available, a very steep increasing unit price may be essential to limit consumption regardless of the actual cost of water.

A.1.1 Flat Rate. A flat charge, independent of water use is levied. This fixed charge may vary for residential, commercial or industrial users or may be determined by the size of the service connection. The advantage of the fixed charge is that it avoids metering costs and is simple to administer. The disadvantages include the high water use. Since the consumer receives no feedback as to actual cost of service, there is therefore, no incentive to avoid waste or reduce consumption. Non-essential uses such as lawn watering, bleeding to prevent service lines from freezing, and water loss through breaks, leaky faucets, and toilets are particularly high where flat rates are used.

Grima (1972) reported a 50% increase in water use in unmetered, flat rate houses in Toronto. Gysi and Lamb (1977) indicated that consumption even during the winter was double for similar houses and conditions in Calgary where a flat rate is charged compared to Edmonton where a unit price scheme is used. Linaweaver et al, (1967) indicate that climate and lawn watering were the most important factors in high water usage in unmetered houses. These uses increase the total water requirements but often are relatively more significant because they substantially increase the peak demand for which the utility system must be designed to meet. Generally, water use can be reduced by over 50% if metering and a flow based charge is used.

Flat rates should not be used where economic efficiency and equitable cost distribution are the basic goals. In some cases, the cost of measuring water use and billing may be sufficiently large to make flat rates attractive.

A.1.2 Uniform Rate. A constant unit price for water is levied regardless of consumption. Metering is necessary but the simplicity results in easy administration. Water conservation is encouraged since consumers pay for what they use but water use will depend on the price level. The low water user is not discriminated against since charges are proportional to service received. Revenue also increases directly proportional to demand, therefore, uniform rates are appropriate where the cost of providing water and sewer service increase in proportion to the volume of water consumed. This is the case for truck systems for which the fixed costs are only about 25% of the total cost. Piped systems generally have declining unit costs due to the high initial or fixed costs; however, long term requirements and costs must be considered. A review of water rate structures in California by Reiter (1977) indicated that utility companies were beginning to realize that no real economic savings are achieved by encouraging large consumption and uniform rates were becoming more common.

A.1.3 Declining Block. A specific amount or unit price is charged for a certain volume (block) of water with the applicable price declining with each successive block. The first block of water is sometimes termed a minimum service charge. Since lower rates are charged for each additional block or portion consumed, the consumer's average unit cost decreases with increasing consumption. The declining block rate is by far the most widely used price structure, 94% of the cities reported in a 1965 study (Anon., 1965). The reason for this popularity is the general assumption that piped utility systems experience a declining average cost both with improvements and system expansion. These "economy of scale" savings are passed on to the consumers who is only charged an incremental rate high enough to cover the incremental cost his demand imposes on the system. If the system has excess capacity then the extra cost for higher demands is small and, therefore, a declining rate is used. In some cases, such as small communities or subdivisions designed for fire protection, the whole system or just some components may never require expansion and there is always excess capacity. However, where system expansion increases, the average or peak load requirements which precipitates the need for expansion, then declining block rates may not be appropriate. In some cases, higher demands may improve the loading and utilization factors of components such as treatment plants, thereby creating a declining unit cost function.

With a declining block, the consumers total water bill will increase with higher demand but at a decreasing rate. In other words the more water you use the less it costs per litre. Thus, water conservation is discouraged since the savings are determined at the lowest unit rate. This method may not be equitable since the lower water users who pay a higher unit cost may be subsidizing the lower unit rates of the higher users. Price levels can be adjusted to return sufficient revenue to the utility system operators. Theoretically this scheme can be tailored to the actual cost of providing service; however, this is impossible to do completely equitably since individual service costs for total volume and peak demands and social costs can not be precisely established.

A.1.4 Increasing Block. The price for each successive block of water demand increases. Both the average and the incremental unit cost and the total cost of water and/or sewage service to the consumer increases with increasing demand. Therefore, water conservation is promoted and rewarded. This scheme is appropriate where increased utilization rates and/or capacity expansion cause the unit or average costs to increase. It has also been used during the recent drought in California when limited water supplies necessitated reduction and limitations on total consumption (*Consumer Reports*, 1978). This was done as a form of social penalty rather than to return revenue to the utility system operators.

This scheme results in the greatest amount of water conservation. It also automatically yields a higher price if demand increases due to lawn watering and other uses. Since the consumer faces higher prices demand increases are modified and demands, particularly peak demands, on the system are reduced.

This rate structure is adequate at returning revenue. Switching to such a scheme would require a stabilization period during which large users would reduce consumption or provide their own service.

A.1.5 Peak Load and Seasonal Rates. The unit price is varied to reflect and provide revenue to pay for the required high system capacity to meet periodic high demands. These schemes recognize that for many utility systems it is the peak demands that determines the capacity requirements and thus capital expenditures of much of the utility (Clark et al, 1971) and attempts to reduce the peak demands may be more cost effective than supplying the facilities to meet them (Russell, 1976). Gysi (1971) reported that the water facilities required to meet the last 12% of a community's summer demand almost doubles the capital costs. Peak load rates attempt to allocate these higher capacity costs to those consumers who are responsible for the peak demands and higher expenditures. Also, by raising the price, the demand on the system is reduced. Peak loads which significantly increase the design capacity and/or operating costs may result from seasonal variations, such as for lawn watering during the summer, daily fluctuations, or the operating characterisitics of particular consumers, such as a seasonal fish processing plant or a school with a demand that is much higher than the rest of a small community. Peak load prices are higher, thus, water conservation and equitable distribution of costs is facilitated. Alternatively, a lower price may be charged for water that is used during off-peak periods. This would improve the loading and utilization factors of components such as storage, pumps and treatment plants which must be sized to meet the peak demands. The objective is to even out the demand on a daily or annual basis by increasing the minimum demand and thus reduce overall costs.

Demand rates are related to the time of use whereas peak load rates are usually determined by hourly peaks. Either can be used in conjunction with other price structures. They are adequate at returning revenue to the utility operators. Furthermore, they are flexible and potentially the most equitable in cost distribution, and they can promote water conservation. However, these rates are difficult to establish and administer and an economical meter to handle such a pricing scheme is not available for residential applications.

Seasonal rate structures may be appropriate where the utility system experiences significant capacity and/or operating cost difference during certain seasons. Northern utility systems which have high heating and other operating costs during the winter or with more expensive or limited water sources at certain periods, may consider seasonal rates for more equitably distributed costs or to reduce consumption. Often seasonal rates are applied to the summer months when peak demands for lawn watering and other outdoor uses are high and strain the system.

Seasonal pricing can be incorporated as a modification of any of the other basic pricing schemes. Standard meters can be utilized and administration costs are not increased significantly.

A.1.6 Fire Protection Charges. The cost of facilities and excess capacity within a utility system to provide fire fighting capability, which is beyond consumption demands, are charged directly to those who benefit from this protection. These costs are primarily related to the storage capacity and size of water mains. The fire protection requirements usually establish the minimum sizes or system capacities; therefore, they are more significant and often dominate the design of water systems within subdivisions and for small communities.

The use of revenue from water bills to obtain the funds necessary to provide fire fighting capabilities is clearly not equitable and distorts the price for water. In some cases a charge is levied based on the proximity of a fire hydrant or there may be a higher water rate for high density residential or commercial areas, or industrial property with high fire flow requirements. Alternatively, this cost can be collected from property taxes which are adjusted to reflect the higher value of lands with fire protection. Whatever the methods used, a separate fire protection charge allows the consumer to identify the cost of this service and to compare it to their benefits (Reiter, 1977). The difficulty in utilizing separate billing is in identifying and establishing the portions of utility system costs which are attributable to the water consumption and fire protection functions.

A.1.7 Social Pricing. A subsidized rate is charged for an established minimum volume of water. The assumption is that water is an essential commodity that should be readily available to all persons regardless of their ability to pay. In addition, there are associated economic benefits to the nation in terms of reduced public health costs, increased productivity, and intangible benefits that are predicated on a healthy population and sanitary living environment. There are numerous problems in determining and administering these "lifeline rates" and ensuring that the goals are attained without subsidizing the affluent.

A critical issue is how to obtain the lost revenue for subsidized service. Other consumers on the utility system could absorb the cost by way of higher prices but this may not be equitable. Alternatively, the responsible government agency could issue "water stamps" or provide for payment of utility bills directly or to provide the necessary funds to the individual as part of welfare payments. The framework for the latter method is already in place and has been utilized. Household water consumption should not be greatly affected depending on the quantity that is established as the subsidized minimum and the method of subsidy.

A.2 Pricing Policy

The primary function of a rate structure and price for water is to recover the capital and operating expenditures for the water supply and distribution and for the wastewater collection and disposal system. Ideally, the rates should be equitable such that costs resulting from various user demands on the utility system are allocated and recovered in proportion to services received. Other indirect issues often enter into the picture in setting pricing policy. For example, the social objectives may include a subsidy to certain users, such as to attract new industry in the hopes of overall economic benefits to the community or the provision of a minimum level of water and sewage service at no charge or at a nominal charge to promote good public health. The social and economic objectives of the community, senior governments and the utility system operators are interwoven to arrive at cost sharing policies and an easily administered, practical rate structure. The price may reflect these political, social and administrative objectives; however, it should also encourage efficiency and cost-effectiveness of total expenditures, both public and private.

The principles and objectives of a pricing policy may include:

1) to provide revenue to recover expenditures;
2) to provide funds for future expansion;
3) to provide revenue to reduce municipal taxes;
4) to distribute costs equitably amongst consumers;
5) to avoid undue discrimination;
6) to be practical, stable and easily administered;
7) to be easily understood and acceptable to customers;
8) to subsidize particular users;

9) to subsidize a minimum level of service;
10) to manipulate demand to minimize costs; and
11) to discourage waste and inefficiency.

In practice, the selection of a price and rate structure is based on equity, expediency, and economics. Because the pricing policy must be designed for multiple criteria, it will involve compromise among sometimes conflicting criteria or goals.

Most water and sewer services are provided by a government agency or a community or public utility. The services are operated as a monopoly and regulated for the public good, usually by a public utilities commission. Utility service is not a normal free market commodity. Water, at least a small amount, is an essential commodity and the willingness to pay is not a factor in determining the price. The charge is for the processing, distribution and collection. The raw material itself is essentially free and usually available, though perhaps at higher procurement costs, in adequate quantities. There is no profit motivation since the service is provided at cost and to all within the designated boundaries of the utility agency.

The revenue obtained from customers should equal the total costs for the system. To recover only costs and to do so equitably, the price at a particular capacity or demand should reflect and follow the particular cost function of that utility system. The cost structure of piped municipal water and sewer systems is typically a high capital expenditure with relatively modest annual operating and maintenance costs. As demand increases, periodic increases in the capacity are required. Sometimes changes in the water source, disposal point, method or level of treatment or other system components may also be necessary due to increases in the demand or environmental requirements. Capacity increases are in descreet quantities, and within each increment the average cost declines until the maximum capacity is reached. Hypothetical short term cost functions are illustrated in Figure A-2.

The long term average costs may be increasing or decreasing depending on local conditions. Increasing cost functions may be due to the development of less accessible water sources, poorer quality water, providing service to more distant or difficult areas, increasing peak

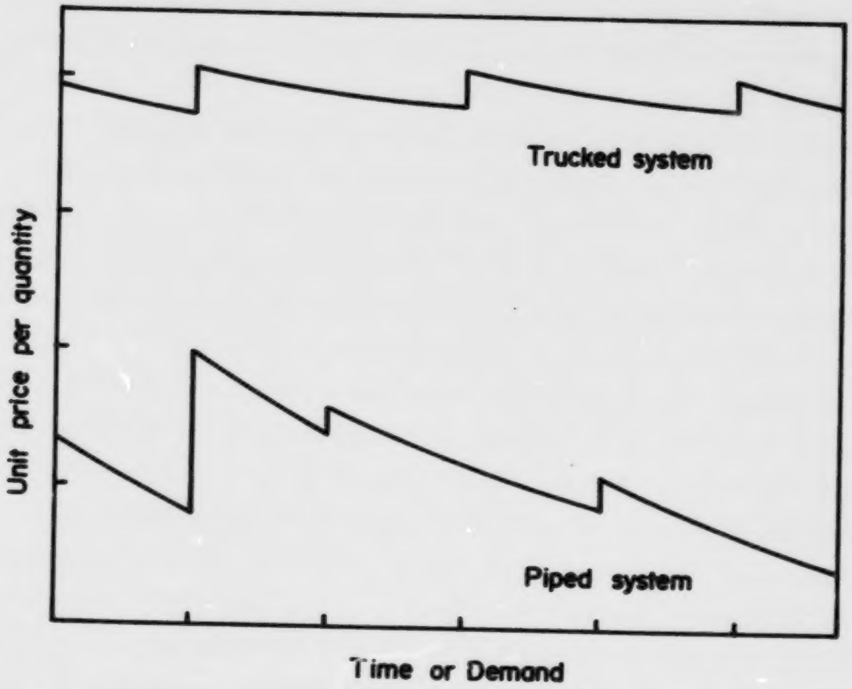

FIGURE A-2. HYPOTHETICAL SHORT RUN UNIT COST CURVES FOR TRUCKED AND PIPED SYSTEMS

demands or other factors. Decreasing cost functions are usually due to economics of scale. The average unit capital cost of most, if not all, utility system components is lower for larger capacity systems. The actual installed capacity is usually for some future demand and the appropriate or most economic design capacity can be optimized depending on the economy of scale, probability of demand, interest rate, and other factors (Meier, 1977). The most significant variables in design capacity and therefore capital costs of piped distribution systems and local storage are usually the maximum daily demands plus the fire flow. The expenditure to develop a water supply is linked to the annual or average daily demand and the expenditures for water supply, sewer outfall and trunk mains, treatment systems and pumping facilities are linked to the maximum daily demand (Howe and Linaweaver, 1967). Truck systems typically have low capital costs, short life and significant operating costs, primarily labour. There is little or no economy of scale or overcapacity within the delivery system. Therefore, the cost function is usually quite different than that for conventional piped systems as illustrated by Figure A-2.

Obtaining sufficient revenue can be easily achieved through the various rate structures. For example, a fixed charge per customer, or a price based on the average cost per unit of water can be used; however, these may not be equitable. The distribution of costs among various services and users causes the most difficulty in establishing rate structures. As indicated above, the capacity costs for standby and peak requirements are significant and often a minimum charge is levied on consumers, regardless of the amount of water used. This can be done by a higher rate for the first units of water use, a minimum charge which includes a certain volume, or a separate bill for this fixed cost. The last units of demand for water may precipitate the need for increased storage or treatment capacity and the resulting expenditures can not usually be attributed or allocated to a particular individual or group. Given that the total cost of servicing specific consumers cannot be determined, some price discrimination is unavoidable (Mann, 1977). Knowing the general form of the cost function will assist in establishing a rate structure policy but much more effort may be required to translate this into an actual pricing policy and price levels. Given that the capital and operating cost structure, both short and long term, of a utility system cannot usually be precisely determined, some inefficiency is unavoidable.

With these social, political and technical constraints, it is no wonder that "the procedures for designing water rates have generally been on trial and error assumptions applied to the sales records of the particular community" (American Water Works Association, 1954). Studies of price and rate structures even within the same region indicate that they are rarely based on logic and comparisons are virtually impossible (Argo, 1962; Reiter, 1977). Often the only criteria they meet is the collection of sufficient revenue to meet expenditures.

A.2.1 Marginal Cost Pricing. The non-economic criteria that may influence pricing policies should not deter economic analyses. Grima (1972) and Chan et al (1976) present detailed economic analysis for utility systems with increasing and decreasing average cost functions. They agree that the water rate schedule should reflect the marginal cost curve such that the price at a particular demand should equal the cost of supplying or satisfying that demand. In classical economic theory for a free market commodity, the resource is efficiently allocated when the price is set equal to the marginal cost of production. Although somewhat distorted, this is also applicable to utility systems (Hirshleifer, DeHaven, and Milliman, 1960). Marginal pricing allows the consumers to satisfy their demand at a price that reflects the costs incurred to provide that service. Conversely, the total or individual savings afforded by conservation reflect the actual savings therefore efficiency is facilitated.

Until physical facilities are fully utilized, the marginal costs of additional demand are only the variable costs such as power, labour and chemicals. Once the existing facilities are at capacity, further demands necessitate discreet additional capital expenditures. Changing prices with each capacity expansion would be confusing to the customers and difficult to administer, particularly for small systems or where large variations in total annual costs are experienced. Therefore, the long term marginal cost should be utilized in determining the marginal price. This may result in an excess of revenue being collected where long term average costs are declining (Grima, 1972).

A literal interpretation of marginal pricing is not always necessary or even correct or desirable. Such economic models do not always precisely predict the free market forces and are further distorted when it comes to a commodity such as water. Also, consumers do not always act rationally, at least in economic terms. However, such a goal is commendable and is probably better than other pricing policies such as flat rate charges or a single average cost price which may have no economic basis and will discourage efficiency.

As a goal, therefore, the pricing policy should lean towards the long term marginal total cost of running the utility system, and the unit price should follow the average cost function of that particular system. For example, where average costs are decreasing, so will the marginal cost and so should the marginal price. Any of the flow volume based rate structure can lead to economically efficient outcomes by designing them such that the prices at the margin are equal to the incremental cost (Chan et al, 1976).

A.2.2 Subsidies. Often subsidies are incorporated into the capital or operating costs and this is reflected in the price charged for water and sewage service if only the utility operators costs are recovered. Subsidies may be used to facilitate the overall social, political or economic goals of the federal, territorial, provincial or municipal government or private industry, such as in company towns. These goals may include the promotion of good public health, reduction of pollution, redistribution of wealth and industry, to attract employees, and many others.

Subsidies may take many forms, depending upon the goals and mandate of the agency involved. Capital grants are sometimes provided for all or portions of specific facilities such as trunk mains and treatment systems or they may be general grants for capital and operating costs. Low interest guaranteed loans are often available to incorporated municipalities while utility systems for small communities in the north may be largely supplied and operated by government personnel. Operating costs are also sometimes subject to various forms of subsidies such as through grants or operating assistance. Direct subsidies to consumers may take the form of price reductions to particular users, such as new industries, or a nominal or no charge for a minimum level of water and sewer service. The former are usually initiated by the municipality while the latter may be senior government agencies who are responsible for health and sanitation improvements. Welfare recipients and persons on fixed income may also receive cash subsidies directly or through free or low priced service. These various types of subsidies, plus others are not mutually exclusive and are often present within the same utility system.

The Federal government has many subsidy schemes that affect water and sewer systems. The provinces also have cost sharing and grant policies and programs, The Northwest Territories Water and Sanitation Policy, which includes capital and operating subsidies to incorporated municipalites and communities, was outlined by Cameron, Christensen and Gamble (1977). A study of municipal services in the NWT warned of the possible inefficiencies resulting from the generous capital grants available to the municipalities (White, 1976).

The heavy involvement of government in small northern communities and Indian reserves often resulted in water and sanitation services being supplied at a nominal charge. There was of course no "money tree" and the same resources are required to install and operate utility systems regardless of the revenue recovered. Subsidies in municipal services were hopefully, justified by their overall cost effectiveness due to benefits to society. There was, however, a danger that they could lead to inefficiency. For example, a direct or indirect subsidy that results in a lower than economic unit price encourages an "artificial" higher demand and sometimes outright abuse. This high demand sooner or later necessitates undue operating and capacity expansion costs, which may be paid for with further subsidies.

This does not mean that all subsidies should be dropped. However, they should be subjected to economic analysis to ensure that their implementation in cost does effectively achieve set goals and at the same time does not induce inefficiencies in other systems. It is suggested that this may be achieved by utilizing a marginal pricing policy. The price for the last unit of demand should not be subsidized and the total incremental capital and operating costs should be recovered. Minimum demands could be subsidized directly by corporate or personnel welfare type payments or indirectly through prices that do not recover the grants, loans, or other resource committments by government. The unit price charged could be a varying percentage of the unsubsidized price, decreasing to nil at an established normal demand or in proportion to the consumers actual demand. A free initial quantity can also induce waste and inefficiency up to that quantity. Therefore, either a percentage of the unit cost, however small, based on the quantity used within that initial volume should be charged or else the level should be sufficiently low to ensure negligible inefficiency.

APPENDIX B

TOILET ALTERNATIVES

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B. TOILET ALTERNATIVES

Of all the household water using activities, toilet water usage has received the greatest notoriety. Toilets use more water than any other fixture in the home, accounting for approximately 40% of the average household's total water demand. For a household of four persons on a municipal piped system, the normal per person consumption would be 225 L/d. If 40% of this is used for toilet flushing and the average conventional toilet requires 20 L/flush, the toilet will be flushed an average of 4.5 times per person per day. On an individual basis, this means that each person flushes an average of 90 litres of potable water per day "down the drain" in order to transport 1.5 litres of human waste to treatment and/or disposal facilities.

An important aspect when estimating toilet water use or the number of flushes per person per day is the type of household water supply and sewage disposal system. Data from Yellowknife, NWT (Cameron, 1977) indicates that the average total consumption is 95 L/person·d for a fully plumbed house on a trucked system. If 40% of this is used for flushing a 20 L toilet, this will amount to 1.9 toilet uses per person per day. This is in the low range of values reported in the literature for rural household toilet uses per person per day: 1.6 (Seigrist, et al, 1976), 2.8 (Kalb, et al, 1978), 2.3 (Witt, et al, 1974) 3.7 (Ligman, et al, 1974) and 5.0 (Laak, 1972). A low value could be due to psychological or intended water conservation practices. For example, the toilet may not be flushed after each urination or the flush water volume of the conventional toilet may be reduced. Both of these would show an apparent less frequent toilet usage. It is interesting to note that if a low water use toilet were installed, the number of flushes per person may indeed increase. Also, the number of hours that individuals spend at home is an important consideration in household toilet usage values. With this in mind and looking at the literature, there seems to be no obvious or meaningful average value for the number of toilet uses per day. Many reports have used a value of five uses per person per day as a convenient estimate but for the purpose of this report four may be a better value. There is also the possibility that the toilet will be used to dispose of cigarette butts, facial tissues and anything else small enough to be flushed away. Development of proper user habits are essential to prevent unnecessary waste. There are also several toilet alternatives available which will reduce or even completely eliminate water use.

Water savings can be achieved in existing conventional flush toilets with the aid of several inexpensive toilet tank inserts or replacement parts. These are summarized at the end of this Appendix in Table B-5 with a list of suppliers following in Table B-6. Where new fixtures are to be installed, there are a variety of water saving models available, many of which cost just slightly more than conventional models. A step further are the non-aqueous or self-contained systems which do not require any water. Water conserving and non-water using toilets are summarized at the end of this Appendix in Table B-7 with a list of suppliers following in Table B-8.

B.1 Conventional Toilet and Modifications

The quantity of water used by conventional flush toilets has been reported to average 20 L/flush, the exact quantity varying from 15 to 30 L/flush, depending upon the flushing action of the toilet (Milne, 1976). Within the average household, the toilet is flushed approximately 1.6 to 6 times per day per person. For this report four flushes are considered average. For a typical four member household on a piped system, this would represent a toilet water usage of 320 L/d.

There are four basic flushing actions used by conventional flush toilets: washdown, syphon jet, syphon vortex, and blowout. They all operate on the same simple principle with their name indicating the essential features of their flushing characteristics. The syphon jet is the most common of the four.

Flushing action of a conventional toilet is initiated by depressing the handle on the tank which opens the flush outlet valve in the bottom of the reservoir tank. Water flows from the tank, entering the toilet bowl through a series of jets located in a hollow flushing rim which encircles the top of the bowl and through an additional priming jet located at the bottom of the bowl. Water entering the rim washes down and scours the inner surface of the bowl clean. Beyond the toilet bowl is the integral trap which provides a water seal to prevent sewer gases from escaping back into the room from the sewage collection pipe. The height of the trap maintains the water level in the toilet bowl and as water rushes from the tank into the bowl and fills the trap, the head differential causes syphoning of the rest of the water out of the bowl. Depending on the flushing action of the toilet, the purpose of the priming jet is to start the flushing action by increasing the velocity and/or quantity of water entering the trap. The greater the velocity of the flush water, the smaller the quantity required per flush.

In the tank, the loss of water causes a float ball to lower, opening a valve on the water supply line. The tank begins to refill and at the same time additional water is supplied to the bowl through the open tank valve. When the tank is empty, the outlet valve in the tank closes and the tank begins to refill. During the filling cycle, the float valve also provides sufficient water to create a seal in the bowl's trap. The float closes the water supply valve when the tank is full and the toilet is ready for another flushing cycle.

The maximum flow rate is the most significant factor for efficient flushing. The water flow must be sufficiently vigorous to scour the inside of the bowl and expel all wastes to maintain an acceptable level of sanitation. This is a function primarily of the height of water in the reservoir tank. The lower the head the larger the volume of water required. This means that a volume of water must be stored and released quickly into the bowl. Bailey et al, (1975) suggest that in most cases the toilet reservoir is designed so that the amount of water and its height are more than sufficient for adequate flushing. Such designs are no doubt influenced by the low cost of water and the supposition that using more water makes the toilet operation more sanitary. Based on this premise, flush volume reducers are designed to displace or hold back a quantity of water in the toilet reservoir without effecting the water level or head, thus using only the amount necessary for adequate flushing.

B.1.1 Plastic Bottles. The simplest and least expensive method to displace water in the tank is to insert a couple of plastic bottles. The water displaced and saved will depend upon the size and number of bottles, but a reasonable estimate would be 1 litre per flush per bottle. The bottles should be filled with water and weighted with a small stone or other object to keep them from floating around in the reservoir tank. If a bottle does shift and jam the flushing mechanism any resulting leak could waste far more water than was saved from reduced water for flushing. Filling the bottles completely with sand has also been suggested, but they would have to be adequately sealed to prevent the sand from escaping since it could lodge under the flush valve and cause a continuous leak or clog the flushing rim jets.

B.1.2 Bricks. Bricks have also been commonly suggested. They displace a volume of water equal to their cubic measurement, usually a little over 1 L (Sharpe, 1974). Unfortunately though, most tanks do not empty completely, so a brick lying on the bottom of the tank is almost useless. If stood on end there is a real danger it will topple over and crack the tank. If multiple bricks are used, they could inhibit the flow of water around them and reduce the force of the flush to perhaps an unacceptable level. Some bricks will also deteriorate in water after a short time and the particles of brick can clog the water jets around the rim of the bowl and/or lodge under the flush valve resulting in a continuous leak. Given the potential hazards associated with bricks, they are discouraged for use as volume reducers.

B.1.3 Float Assemblies. Another form of toilet modification consists of bending the float arm to lower the water level in the reservoir. Sharpe (1974) suggests that this is usually not a good idea because unsatisfactory cleansing of the bowl may result from the decreased head with which the water moves through the toilet. Instead, there are several improved float assemblies or ballcocks on the market which will not impair flushing efficiency. These assemblies are easily installed and costs range from $6. to $10. The quantity of water that will be saved with these devices will be determined by the efficiency and type of toilet. However, water levels and/or quantities can be adjusted to use the minimum amount of water necessary, and some will facilitate the detection of leaks. In the case of the latter, there are very few figures available which show how much water is lost due to leakage and which could therefore be saved. Schmuk (1977) suggests that a leaky toilet could waste more water per year than a family would use for toilet flushing.

B.1.4 Dams. Commercially available are several types of toilet inserts, usually referred to as toilet dams, which wall off a section of the toilet reservoir. They are placed in a verticle position sealing against the sides and bottom of the tank, thereby, preventing the lower side portions of water from leaving the tank when the the toilet is flushed. There are a few types which are adjustable so that the minimum amount of water for efficient flushing is released. Easily installed, costs will range from $4. to $8., with most averaging around the $8. mark. Manufacturers have estimated savings to be as much as 36% to 42% of the water normally flushed away, however, according to Nelson (1977), savings will not only depend on the particular toilet in which these dams are installed but also on the age of the toilet. In his opinion, only about 4 L/flush (approximately 20%) savings can be counted upon and still maintain a good strong flush.

B.1.5 Weights. Some devices inserted into the toilet tank allow for a complete user manipulated control over flush volumes. The simplest of these are weights which attach to the ball chain or rod. The user controls the flush volume by holding down the flush lever until the desired flushing has occurred. By releasing the lever the weight immediately stops the flow by forcing the stopper back into the flush valve seat. Savings will vary according to user habits, but manufacturers have claimed that every home can save as much as 30% to 40% of their normal flushing water. However, a completely user manipulated device such as this, which negates the normal operation of the toilet, may not be appealing to most since one has to remain holding down the flush lever during the flushing action. The Washington Suburban Sanitary Commission (WSSC) has suggested that fishing weights or lead solder may accomplish the same result at little or no cost. Costs for the manufactured type ranges from $0.80 to $1.50 with more complex types costing as much as $8. each.

B.1.6 Dual Flush Mechanisms. Another type of toilet volume reducing device is the dual flush mechanism which offers the user a choice in flush quantities. There are two types of dual flush mechanisms, which are defined here as single action and double action. With the single action type, when the toilet is flushed normally, only a portion of the total tank flush water is released due to either a counterweight, floating cylinder or air bleeder attachment which prematurely closes the toilet valve. For a full tank flush, the flush lever is held down until all the water in the reservoir has been discharged, after which the lever is released. The double action type offers the user the option of choosing between a low volume flush or a full tank flush without having to hold the flush lever. This is accomplished through a kit which replaces some of the parts in the toilet reservoir tank, including the flush lever. With everything installed, the new flush lever can be moved in two directions, down for the low volume flush and up for the full tank flush. One model offers three flush options; down for 5.7 L, up for 13.2 L and the full tank if the flush lever is held in the up position. Reported savings range from 30% to an optimistic 75% of the normal toilet usage, but again savings will vary according to user habits. Costs vary from $3. to $15. depending upon the particular device and type of toilet in which they are installed. These devices appear to offer significant savings in conjunction with user convenience but unfortunately, the poor quality of materials and design of some of the more complex models can result in leakage which negates any water saving through flushing.

B.1.7 Replacement Tanks. A more expensive modification are the replacement tanks. These are designed to replace the whole reservoir tank with a manufactured pressure tank cartridge and cover and mount on the existing toilet bowl. The kit comes complete with everything required for the change-over, including matching of original colours. The principle of operation is that water enters the empty cylinder compressing the air inside, stopping when the water and air pressure are equal. Initiating a flush cycle opens the valve and allows the compressed air and gravity to force water through the bowl. This is equivalent to increasing the head of water and, therefore, the flushing velocity which in turn reduces the water requirements. Savings have been claimed up to 60% of the water required by conventional toilets with usage varying from 9.5 to 11.5 L/flush, however, savings will depend upon the pressure in the water system to which they are attached. With low or fluctuating line pressures, such as those which may exist with a individual pressurized water system, the efficiency may be impaired, particularly when other fixtures are in use or when flushing is frequent. Cost for the pressure tank and cover is $85. to $95.

B.1.8 Operation and Maintenance. When modifying the conventional toilet by any of the preceeding methods, Sharpe (1974) cautioned that if too much water is displaced or the water level is lowered too drastically, toilet malfunctions may result. Not all devices work as well as others and in some cases leaks may occur or two flushes may be required to remove solid materials from the toilet bowl, resulting in no water being saved. In addition there is also the possibility that lower toilet discharge rates will cause blockages in gravity drain lines, unless other high-rate fixtures discharge into the same line. A theoretical analysis by Cole (1975) indicates that toilet discharges down to 7.6 L/flush do not reduce the flow rate substantially and should pose no problem. However, the depth of flow drops substantially when less than 13.25 L/flush is used and may be a problem for solids transport. He suggests that 100 mm house connections be considered when low-flow toilets are used.

Consumer Reports (1978) tested 28 of these water-saving devices for toilets, and their overall conclusion was that they couldn't really recommend buying any of them. They felt that a bottle in the toilet tank or a homemade weight for the flush valve would be just as effective as nearly all the products tested. However, they did suggest that if a "gadget" was to be purchased, the toilet dams were the most effective commercial devices for reducing water consumption. Rated as potentially more durable than plastic dams were the types made of stainless steel covered with rubber and the brass dams with foam rubber strips at the edge.

In the same test, weights were judged nearly as effective as dams in reducing water consumption and could be used in conjunction with dams to maximize convenience and water savings. It should be noted that in their classification of weights, they included the varieties which did not require the handle to be held down to clear liquid waste. These types were previously defined here as single action dual flush devices and the weights were those requiring the handle to be held down to clear both solid and liquid wastes; in which case, convenience would be a matter of user opinion. Dual flush units tested of the double action type with two directions on the flush lever were judged slightly less useful than dams or weights in reducing water consumption. It was also found that installation was more difficult, with one type requiring the toilet tank to be removed from the bowl. A dual flush unit of another manufacturer failed to operate reliably and the flushing mechanism of one unit broke. A separate category was given for air bleeders which were found similar to weights in operation, but susceptible to clogging or malfunctioning. Non-adjustable air bleed models required the flush lever to be held down to clear both liquid and solid waste.

Replacement tanks were also tested and found to be far more difficult to install than any of the other devices. Other comments were that they may not work adequately on systems with water pressure less than 240 kPa; they are somewhat noisy at high pressures; and they may not fit all toilet bowls.

The results of these tests indicate that the performance of each toilet modification should be carefully evaluated before installation. This is not meant to discourage anyone from modifying their existing toilet as potential savings usually warrant their installation, but if problems do occur that cannot be corrected, the device should be removed altogether. The potential savings per flush of each type of modification device is given in Table B-1, based on the conventional toilet average water usage of 20 L/flush. The savings are estimates based on a conservative estimate of the manufacturer's claims and the ratings of Consumer Reports, (1978). Actual savings will vary with use and type of toilet.

TABLE B-1 WATER USE WITH TOILET MODIFICATIONS

	Water Volume Per Flush	Water Savings Per Flush*	
	litres	litres	%
Conventional toilet	20	-	-
Bricks or plastic bottles	18	2	10
Weights	14	6	30
Dual flush devices	14	6	30
Dams	13	7	35
Replacement tanks	10	10	50

* Based on conventional toilet average water usage of 20 litres/flush.

B.2 Water Conserving Toilets

An alternative to modifying the conventional toilet is to replace it with a water conserving model. Often this is reserved for new installations, but if replacement of an existing toilet is necessary, a water conserving model may be advantageous and should be considered. An economic analysis may also indicate in some situations that immediate replacement is cost-effective. There are a number of different types of water conserving toilets, some suited to a particular need or situation. In particular, a few low flush toilets are not suited to gravity sewer collection systems and are restricted to use where pumped or septic fields are used. Also, like the toilet modifications, not all work as well as others and here aesthetics and user acceptance are also significant considerations. The water requirements of the water conserving toilets are presented and compared to that of the high water using conventional flush toilet in Table B-2. The characterisitcs of these toilets and a list of suppliers are summarized at the end of this Appendix in Tables B-7 and B-8, respectively.

TABLE B-2. WATER USE OF WATER CONSERVING TOILETS

Toilet Type	Average water consumed per flush litres	Savings over conventional flush toilet litres	 %
Conventional	20.0	-	-
Shallow trap	13.5	6.7	33.5
European 9L	9.0	11.0	45.0
European 6L	6.0	14.0	70.0
European 3L	3.0	17.0	85.0
British dual cycle	6.6	14.4	72.0
Flush valve	12.5	7.3	36.5
Urinal	5.0	15.0	75.0
Air Assisted	2.0	18.0	90.0
Vacuum	1.5	18.5	92.5
Mechanical seal	0.5	19.5	97.5
Marine	1.0	19.0	95.0
Recirculating	0.2	19.8	99.0

B.2.1 Shallow Trap. A number of companies in the United States are now manufacturing a low water use toilet, often referred to as shallow trap toilets. They are no different in appearance from the normal conventional flush toilet, but have a shallower water-trap and smaller water tank with essentially the same rinsing and cleaning action of the conventional models. They are also available in the usual round or elongated bowl designs with costs of $80. to $200., which is only slightly higher than the conventional toilets. Although they are rated to use 13.3 L/flush, only one of the models tested by Consumer Reports (1978) achieved that value. The results of these tests which were performed on standard round-front bowls are presented in Table B-3. The American Standard Cadet and Kohler Wellworth Water-Guard were their clear choices.

TABLE B-3. SHALLOW TRAP TOILET WATER USAGE(1)

Model(2)	Water Use litres	Comments
American Standard Cadet 2122.448	14.0	- water exchange judged good
Kohler Wellworth Water-Guard K3500-PB	15.9	- water exchange judged good
Eljer Emblem 901-0500	14.4	- water exchange judged fair
Sears Cat. No. 49288	16.3	- water exchange judged good
Crane Radcliffe 3143	13.6	- did not wash inside of bowl properly - water exchange judged fair
Artesian C4321	14.4	- water exchange judged fair - tank is insulated to reduce sweating in warm, humid weather
Briggs Conserver 6280	12.9	- water exchange and ability to handle floating waste judged poor
Sears Cat. No. 49435	18.5	- water exchange and ability to handle floating waste judged poor

(1) From: Consumer Reports (1978).

(2) Model numbers given are for white porcelain.

B.2.2 European Low Flush. Somewhat different, but just as aesthetic as the North American flush toilets, are the European Low Flush toilets. Depending on make and country of origin, these toilets require only 6 or 9 L of water for efficient flushing. The 6 L version is a standard in Sweden and the neighboring Scandinavian countries. In addition, there is also a special version originally designed for summer houses which requires only 3 L of water. As for their appearance, they are similar to the conventional American elongated bowl design except that the close coupled water reservoir tank is oval shaped with a flush release knob located on top of the tank.

B.2.2.1 European 3 litre. The 3 L toilet unit is only recommended for connecting to a holding or septic tank, although depending upon local regulations and conditions, it is also possible to connect to municipal sewage systems. Several recommendations are made for installation, such as the distance from the toilet to the holding tank should not be more than 25 meters and the slope should be at least 3 cm per meter. The sewer pipe should be as straight as possible and unnecessary bends and branch pipes should be avoided. Instead of a 90° bend, two 45° bends, or even better, three 30° bends should be used. If a branch pipe from other fixtures cannot be avoided, it should have a top connection and not a horizontal connection. It should also be mentioned that the 3 L toilet comes equipped with a rubber tightening gasket and a plastic connection piece for 75 mm plastic soil pipes. Connection pieces to 90 mm pipes can be obtained at extra cost but for 100 mm pipes, no special connection pieces are available and an adaptor would have to be made. These recommendations are presented to emphasize that for transporting the excrements, a large diameter pipe is of no advantage, since it reduces the pushing effect of the water. In new installations, small diameter sewer pipe would also be advantageous from the point of view of material and handling costs.

B.2.2.2 European 6 litre. A European 6 L wash down toilet, a water saving American toilet, and a conventional American toilet were used in a study by Konen and DeYoung (1975) to investigate the flushing and hydraulic characteristics and the effect of the wide spread use of reduced volume water closets on wastewater treatment plants. They concluded that the American water closets were superior in performance to the European wash down type. On a comparative basis, the European model rated 18 on an established flushing performance test compared to 24 and 24.5 for the conventional and water saving American models, respectively. It was noted, however, that both American units consume appreciably more water, 16 and 11 L versus 6 L. The velocities of discharged wastewater in the fixture drains were not appreciably different for the water closets tested. A composite diagram of their discharge velocities appears in Figure B-1. There were no problems envisioned with transporting solids in sewer drains.

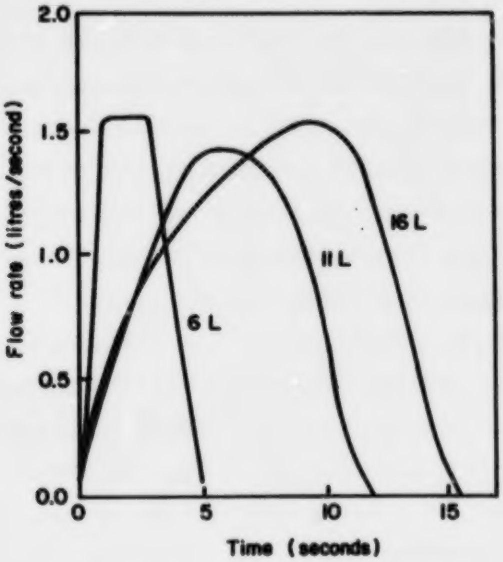


FIGURE B-1. FLOW CHARACTERISTICS FOR 6,11, AND 16 LITRES PER FLUSH TOILETS. (KONEN AND DEYOUNG, 1975)

B.2.2.3 British dual cycle. Another European toilet is the British dual cycle toilet. This syphon toilet uses two separate flush cycles; one for urine and the other for solid wastes. The solid waste cycle uses 9/L flush and the liquid waste cycle uses only 4.5/L flush. The flush cycles are initiated by a short, sharp pull on the flush handle for the smaller amount of water, and a longer, more persistant pull for the larger amount of water. These toilets were installed in low income flats, and test results indicated an average flush of 6.6 litres, a savings of 27% over their normal 9 litre water using toilet (Bailey et al, 1975). Compared to a conventional American toilet, this would be a saving of 65% of the water normally flushed away. Bailey et al (1969), Wenk (1971), and Chan et al (1976) all found that this type of toilet was the most cost-effective alternative of those studied.

A common problem with the European toilets could be with installation, particularly for a retrofit situation. Because they use metric sizes, special or makeshift adaptors must be used until pipe sizes in Canada are converted to metric values; however, two toilets installed in Yellowknife presented no difficulty to qualified plumbers.

Also, North American toilets are designed with the trap outlet located about 30 cm from the back wall, therefore, the toilet sewer drain is roughed in at that same distance from the wall. European toilets have the trap outlet located towards the rear of the toilet (15 cm from the wall) and, if they are installed into an existing drain they will stick out about 15 cm further than an American toilet. In some cases, there may not be enough space in front or it may be inconvenient and a new outlet closer to the wall would have to be installed.

Toilets are designed to meet specific standards which are different for Europe, Britain and North America. In Canada these are prepared by the Canadian Standards Association (1973). Because of these differences, which are to a large extent dimensional, European toilets do not meet present Canadian standards. Thureson (1977) indicated that attempts to market European toilets in North America have been thwarted by protective domestic interests and the major impediment was "the influence from domestic manufacturers on bodies handling matters of national standards and direct or indirect control over the distribution channels." Local amendments to the national standards or new standards can be formulated which would ensure adequate performance but allow non-American toilets to be installed; however, until this is done their use will be greatly hampered.

B.2.3 Flush Valves. Eliminating the need for a bulky tank, flush valves utilize the velocity of water injection directly from the water supply line to produce a swirl effect which syphons wastes through the trap. They are commonly installed in commercial, office or institutional complexes. With usage from 8.6 to 16.2 L/flush, these units generally have a shorter pre-fixed cycle and quicker recovery time than a conventional toilet. Household application will be limited due to their requirement of a 25 mm water service line and possible problems with pressure drops due to the simultaneous use of other fixtures. Installation is usually handled by plumbing contractors, and retrofitting the valve to tank-toilet bowls is uncommon. Capital costs are approximately $100 to $175 and installation costs are about the same as for a conventional toilet.

B.2.4 Urinals. Somewhat similar in operation to the flush valve toilet are the user activated flush valve urinals. When installed with properly adjusted flush valves, some low water use syphon jet models will use less than 4.0 L/flush. Normal models will have usages ranging from 5.7 to 15.1 L/flush. It is important to note the emphasis which is placed on the installation of a user activated flush valve urinal. In some installations, a pre-set timed flushing interval is used where tremendous volumes of water are wasted. As with the flush valve toilets, installation of urinals is commonly reserved for commercial, office or institutional complexes, with consumer acceptance being poor for residential application. Most toilet manufacturers also make urinals, and costs will vary from $80 to $200.

B.2.5 Air Assisted. Air assisted low flush toilets which are controlled by an air/water sequence valve require only 2 L of water per flush. When the flushing sequence is actuated, a flapper at the back of the toilet bowl opens, allowing waste and residual water to drop from the bowl into a secondary chamber under the bowl. The flapper between the two chambers closes but the flush water continues to flow for a short time to create a water seal in the bowl. Towards the end of the cycle, the water turns off and a valve on an air line from a compressor opens to pressurize the secondary chamber. When the pressure builds up, the wastewater is forced out the discharge pipe in a slug. Because of this relatively high velocity slug discharge, this toilet only requires 2 L of water yet it can be used with a conventional gravity sewer system. Although the operation is rather complex compared to a conventional flush toilet, the manufacturers claim low maintenance compared to oil, vacuum or chemical toilet systems. Capital costs for the toilet range from $600 to $675 for the vitreous china models and $800 to $875 for the stainless steel models. The additional capital cost for the air compressor, which will service up three toilet units, is approximately $400. One compressor or a compressed air bottle can supply air to a number of toilets, thereby, reducing the average toilet unit cost when installed in a large building or public washroom. The requirement for a compressor and air hose to the toilets will complicate and increase installation costs, particularly for a retrofit situation.

B.2.6 Vacuum. The opposite of the air pressure assisted toilet is the vacuum toilet system which transports wastewater to a central collection tank, by evacuating the air from the sewer pipe network. The wastewater travels in slugs at relatively high velocities through small diameter piping. After a certain distance, the slug breaks down and is reformed again in traps installed about every 100 m. The system is self-contained, consisting of a vacuum collection tank and vacuum pump, collection pipes, a specially designed low water use toilet and special valves to allow sinks, laundry and other drains to be connected. The vacuum toilet looks like a conventional toilet without the tank but requires only 1.5 L of water for flushing and cleaning of the china bowl. Vacuum systems operate independently of gravity and can transport wastewater up hill to some extent. They require only 40 mm to 80 mm PVC or ABS pipe which is smaller and lighter and, therefore, less expensive to install than conventional gravity sewer pipes. Vacuum mains can be laid in the same trench as the water mains with less concern for cross-connections, contamination, or infiltration. There is less heat loss due to the smaller diameter piping and combined with its ability to allow some movement, vacuum sewer systems will facilitate underground installations in areas with permafrost and seasonal frost. Utilidor designs and costs could also be decreased through the use of smaller piping. It is also possible to transport blackwater (toilet waste) either together with greywater (all other household waste) or separately which allows separate and perhaps lower cost treatment and/or disposal. Once collected in the vacuum tank, the wastewater can be either collected by truck, pumped into a municipal sewer system, or treated and disposed of on-site. The major disadvantage of vacuum systems is the relatively expensive cost of approximately $2000 to $3500. for an individual household toilet system. Retrofit installations could be quite difficult and may prove to be impractical in some situations. The need for back-up pumps and the power requirement may also be a disadvantage to this type of system. However, because one vacuum tank and pump can be used for a number of toilets within a building or used to collect wastewater from a number of buildings or perhaps a whole subdivision, this system appears to be more appropriate and cost effective for these conditions. Total and average costs would have to be estimated for each case but would be considerably lower than for an individual household system.

B.2.7 Mechanical Seal. There are two types of mechanical seal toilet units; portable and permanent, both of which use very little water for flushing. Portable, or self-contained models consist of a bowl and seat which is attached directly over a small 15 to 25 L holding tank. Most of these units also include their own 7.5 to 25 L fresh water tank which provides the flushing liquid. To flush the toilet, a pedal or lever is pushed which opens a sliding or flapper valve at the bottom of the toilet bowl and at the same time pumps some water through the flushing rim of the toilet bowl. The waste drops into the holding tank and a swirl of water rinses the bowl and provides a water seal. When the tank is full, the whole toilet, or in some models only the holding tank portion, is taken out for disposal of the contents. The fresh water reservoir must also be periodically refilled and deodorizing chemicals are usually added. Depending on the model, the units can handle 40 to 150 flushes before they must be emptied. These units are usually quite small requiring no plumbing and are commonly used in motor homes and trailors.

Permanent mechanical seal toilet models consist of basically the same toilet; however, they are connected to a water supply line and discharge directly into a separate large holding tank, which usually receives wastewater from the other household fixtures as well. The activation of the flush lever or pedal opens the sliding or flapper valve as well as a self-closing valve on the water supply line. The stream of water cleans the toilet bowl and provides a water seal; however, these units will also operate by simply pouring water into the bowl. Because of the small volume of water used, 0.5 to 0.8 L, the receiving tank must be located almost directly under the toilet. Bends of less than 90 degrees can be installed, but there should be no horizontal transport of wastewater. The cost of mechanical seal toilets varies from $75. to $175., with the higher priced models usually including a small holding tank. A typical cost would be approximately $90. A system with a toilet and a steel 680 L holding or septic tank is available for $225. The portable models require the additional operating cost of deodorizing chemicals.

B.2.8 Marine. Marine toilets which use a hand or electric pump to bring water into the bowl and discharge the waste were developed, as the name suggests, for shipboard use. The advantages of marine toilets are the low water requirement of about 1 litre per use and the ability to pump wastes uphill. When a valve is turned the same pump which brought water into the bowl is used to eject the wastes. Distances to the receiving tank, if one is used, should be short due to easy clogging of these units. Another possible advantage would be the ease in which they could be adapted for use as recirculating toilets; however, these units are relatively complicated to use and when recirculation is a consideration it would generally be best to use toilets specifically designed for that purpose. Cost for the marine toilets vary from $100. to $400., the latter price for a delux electric model. Power consumption of the electric models would be a nominal amount.

B.2.9 Recirculating. Recirculating toilets use a manual or electric pump to recycle filtered and chemically treated wastewater to rinse the bowl and flush the toilet. These types of toilets are notable for their use in airplanes as well as in boats, motorhomes and trailers. The units are initially charged with odour control and colouring chemicals and some water, which need not necessarily be fresh water. A disadvantage is that the chemicals themselves have an odour which may be objectionable, and if used too long, the recirculating fluid will develop an objectionable odour and colour. Small units, about the size of a conventional toilet, have a 10 to 40 L holding tank and can be used for 50 to 150 flushes before the holding tank must be emptied and recharged. Water requirements are about 0.14 to 0.20 L/flush. Chemical costs will amount to approximately $2. to $15. per 1000 flushes, the lower price being for bulk purchase. A typical southern household cost would be $15. to $110. per year for chemicals. These units are available as self-contained portable units or they can be permanently installed. The permanent models usually incorporate a refill mechanism which can be hooked directly to a water supply line, thus, eliminating handfilling and rinsing when recharging the unit. They are also connected directly to a sewer drain and can be emptied simply by pulling a lever which opens a valve on the internal holding tank. For a typical household, emptying and recharging would have to be done every 2 to 10 days, depending on the size of the unit. Rather than a hand pump to flush the toilet, many of the permanent units have an electric motor which only requires a nominal amount of electricity. One model has both electric and manual operation. A permanent system can be used in buildings using a holding tank or septic system since manufacturers claim the chemicals will not interfere with their biological activity. There appears to be no reason why they could not be used in a municipal gravity sewer collection system. Cost for these units vary from $90. to $350, the lower price being for the portable models and the higher range for permanent electric models.

There are also large capacity recirculating toilets available. These have self-contained or external holding tanks which are usually 200 to 500 L. The 270 L units can be used for 1000 flushes before they require emptying and recharging with 60 L of water. Fresh water requirements are therefore as low as 0.06 L/flush and chemical costs would be about $2. to $5. per 1000 flushes for bulk purchase. These toilet units cost approximately $1200 and complete outdoor public washroom modules can cost up to $3000.

B.3 Non-Water Using Toilets

For many of the recent occupants and conventional planners of communities in the north, the ultimate goal in human waste disposal is the installation of a piped water and sewer system with a water flush toilet in every house. Orr and Smith (1977) stated that while there is no question that the use of water to transport wastes in sewer collection systems has brought great sanitary benefits to the urban environment, the use of these same systems, coupled with our failure to provide adequate treatment has caused public health and pollution problems in the lakes, rivers, and streams of the industrialized world. A number of authors (Orr and Smith, 1977; Love, 1975; Rybcznski *et al*, 1973) feel that in light of the advances made in the technology of self-contained toilet systems, the insistence on continued use of the standard flush toilet and the conventional sewer system should be carefully reconsidered in the south as well as the north.

Non-water using toilets will reduce average household water demand by approximately 40%, therefore, the water related economic benefits can easily be estimated. Besides this, however, elimination of the need for a water supply presents a significant advantage to some applications, particularly for situations that would otherwise not require a water supply. The same thing applies to the non-water using toilets that destroy the waste and therefore do not require waste collection. These include the incinerating and the compost toilets, both of which produce only a small volume of ash residue. Thus, any pollution or public health problems with human waste are eliminated and the organic as well as hydraulic loading of treatment plants or septic fields is greatly reduced. Recycle systems can also provide this advantage to some extent, depending upon the method and level of treatment and sludge handling. The advantages of not requiring a water supply or waste collection system as well as the pollution reduction benefits will be difficult to quantify in terms of dollars. In some cases, they may be the only practical alternative because of these characteristics. For a normal household, the greywater must still be handled and the use of these systems is often tied to the options available for greywater treatment and disposal. A summary of the characteristics of non-water using toilets and a list of suppliers are presented at the end of this Appendix in Table B-7 and B-8, respectively.

B.3.1 Bucket. Many northern communities rely wholly or in part on service vehicles to supply water and remove human waste from homes and other buildings. Although individual pressure water systems and low water use toilets connected to sewage holding tanks are becoming more prevelant, the majority of unsewered homes in the north still rely on bucket toilets. These toilets, also referred to as chemical toilets, contain a lift-out bucket which is removed and the waste disposed of in a pit privy or by some other method. The bucket is cleaned and charged with a chemical to reduce odours. The more common method of use in northern homes is to insert a heavy plastic "honeybag" into the bucket. When the bag capacity is reached, it is manually removed and replaced with a new bag. Bucket toilets are placed within the home and are used basically because outdoor privies cannot be used in permafrost areas. The use of plastic bags facilitates collection, but this method of handling human waste constitutes a major sanitation and health problem in the communities. Breakage and spillage of bag contents during or between collections is a common occurance and during winter bags can be covered by snow and not found until spring. The ground, drainage paths and ponds within the community can thus become contaminated. Ultimate disposal of the "honeybag" contents can also present problems. The bags are usually disposed of at the local garbage dump or in a separate area or sludge pit.

There are serious aesthetic and public health problems with the "honeybag" or bucket toilet system; however, it is usually a considerable improvement over not having any organized community waste removal system. The system is simple, low technology, but collection can be unreliable. The bucket toilet is portable, easily installed, does not use any water or energy and does not have any moving parts. The capital cost is $30. to $100., replacement "honeybags" cost about 5 cents each and deodorizing chemical costs are minimal. Typical collection charges in the NWT are $1.00 to $2.25 per pickup or approximately $15. to $60. per capita per year (Dolton, 1978). A well designed and operated system with collection 5 times per week could significantly reduce the manhandling and breakage problems but would be considerably more expensive.

B.3.2 Packaging and Freezing. Two toilets which are basically modifications on the bucket "honey bag" system are the packaging and freezing toilets. These units offer advantages over the bucket toilet in the in-house aesthetics and handling as well as transporting and disposal stages, but present the same problems in ultimate disposal of undiluted human waste. The packaging toilet receives wastes in a plastic lined bowl. A continuous band of plastic is drawn through the bottom of the bowl, and after each use is heat sealed to form a series of packages sometimes referred to as "sausages." These "sausages" are collected under the toilet in a plastic lined bag which is large enough for approximately 40 uses before it must be removed and replaced. The plastic tubing, which is sufficient for about 120 uses before it must be replaced, is drawn down through the bowl by means of an electric motor. This toilet system requires fresh liners, collection bags, and a small amount of electricity for the motor and heat sealing mechanism. The packaging toilet costs considerably more than the bucket toilet at $500. to $1000. but handling of the waste is improved and breakage problems are reduced due to the isolation of small quantities of waste in separate "sausages." Basically, the freezing toilet is a toilet seat placed above a small freezing compartment which is lined with a plasticized bag. Waste falls into the bag where it is frozen and stored at a temperature of about -20^{o}C. The freezing of the waste prevents decomposition and odors and handling of the waste is much safer, easier and more aesthetically acceptable, providing the waste bag is not allowed to defrost or there is not a power failure. Waste heat circulated from the compressor to the toilet seat allows for user comfort. The cost is slightly less than the packaging toilet at approximately $400. per unit with a electrical requirement similar to that of a small refrigerator. The packaging and freezing toilets also require a collection and disposal system.

B.3.3 Incinerating. Incinerator toilets utilize either electricity, propane or natural gas to burn up solid waste and evaporate liquids, leaving only sterile ashes. The toilet seat is located above a combustion chamber which is usually lined with a special paper insert to receive the waste. By lifting the toilet seat cover, a timer which controls the incineration cycle is set; incineration begins automatically by closing the cover or on some models by manually setting the timer switch. The waste is dried and incinerated, leaving only an ash which must be removed about once a week. Most types are equipped with blowers to remove odors, heat, and moisture and for this a separate vent must be provided. The advantage of these units is that they completely destroy the waste, thus, eliminating the need for collection and disposal.

These types of toilets are relatively expensive with a cost range of \$650-\$1000 but are relatively easily installed. A major disadvantage is the large amount of energy required to operate them. For example, the electric models draw 0.9 to 1.4 kW·h per cycle or 5250 to 8200 kW·h per year for a household of 4 with an average of 4 uses per capita per day. The evaporation of liquids may also produce objectionable odors within the community.

B.3.4 Composting. Like the previous non-water using systems, the use of composting toilets to manage human waste within the home environment represents a complete break with conventional plumbing. The prototype of a composting system was first installed in a home in 1939 by its Swedish inventor, Carl Lindstrom, but is a relatively new concept in the technology of waste disposal in North America (Stoner, 1977). Units based on early designs use a large, well ventilated container located in the basement of buildings, and receive wastes through verticle chutes connected to the toilet and kitchen. The container is vented through the roof of the building. The container has three sloping sections: the excrement chamber; the refuse chamber; and the storage chamber. Decomposition generates heat which induces natural convection and draws air through and over the compost heap, keeping it nearly aerobic and carrying away evaporated moisture. As the organic material decomposes, it falls slowly down the inclined, ventilated slope, which is the key to the process, to the storage chamber where it remains until manually removed. Decomposition and drying reduces wastes to about five percent of their original weight. Because of the large size of the storage chamber and the length of time the mass undergoes decomposition, removals from the unit are only required once every two or three years, even when in constant use. To ensure that the process continues unimpeded, chemicals should not be introduced into the system, nor water in great quantities. A major drawback is the large size of the composting container, which often prevents installation in homes already constructed and presents difficulties in those which lack a basement. Since most homes in permafrost areas do not have basements, this type of unit may be impractical to install in these areas. In addition, aerobic decomposition occurs at temperatures of about 32°C to 35°C, and because of this requirement, the system must be insulated or installed in a warm basement for cold weather operation.

The development of small compost toilet units which utilize auxiliary heat and forced aeration to promote rapid decomposition of the waste are the most recent innovation in composting toilets. The concept behind the design of these units is that, by providing an optimum environment for the microbial process, the waste can be stabilized in a relatively short time, allowing the composting unit to be kept small. The units, as designed, are only for toilet wastes and only require one chamber. Waste is received and stored under the central chamber, and most require only slightly more floor space than a standard water closet, and therefore, are applicable as a retrofit alternative. The electrically heated units are relatively easy to install, requiring only an exhaust vent and an electrical outlet. A major disadvantage of these small compost units is the power requirement which would make operation quite expensive with the high energy costs of the north. Also, because of the small capacity of the compost chamber they are best suited to low, constant use and can not handle shock loading of organic or liquid wastes. If overloading or operational problems occur and the compost becomes septic, odours from the compost can seep into the home environment in spite of forced draft ventiliation systems. Orr and Smith (1977) commented that the aesthetics and sanitary qualities of the present units leave much to be desired. Although the waste is quite rapidly decomposed, it is accessible to flies and other vectors each time the toilet cover is opened. The close proximity of the waste to the toilet seat opening is also aesthetically offensive. McKernan (1976) noted the difficulties experienced with units placed with selected families in an experimental program in Northern Manitoba and concluded that constant attention and disciplined use on the part of the homeowner are necessary for good performance. If the units were to be distributed in volume to northern communities, major problems would be experienced in keeping the units maintained and operating properly. If liquid waste could be separated, either in the bowl or compost chamber, no auxilliary heat would be required and the process would be more stable (Orr, 1978).

Costs for the larger compost units are approximately $1,500. to $2,500 each, including appurtenances but not installation costs. The small electrical units are somewhat less at $500. to $1000. each. The power requirement of the small electrically heated units ranges from 1.2 to 8.75 kW·h per day.

B.3.5 Synthetic Fluid. Synthetic fluid toilets use a special odorless chemical fluid that has a specific gravity either higher or lower than water and is immiscible in water, such as mineral oil, as the flushing medium. The use of such a synthetic fluid as the waste carrier eliminates the need for water and allows for fast and easy gravity separation of the carrying media from the wastes. When the conventional toilet is flushed, the waste and transporting fluid discharge via a sewer collection pipe into a holding tank where waste materials and synthetic fluid separate. The synthetic fluid is drawn from the tank, filtered and held for recycle. A problem encountered by Matthew and Nesheim (1973), testing a prototype non-aqueous system utilizing recirculated mineral oil as a collection and transport media, was bacteria build-up resulting in odor problems. They recommended the routine use of an oxidizer-bactericide to eliminate odors resulting from the accumulation of organic solids and the associated bacterial growth. Also in this demonstration project, installed and operated at the Mount Rushmore National Memorial, South Dakota, oil loss was found to be a function of facility usage rate and the operating level of waste in the waste sump. During low and high use periods, there was a loss of 14.4 and 178 L of oil per 3785 L of wastewater, respectively. Milne (1977) commenting on household installation stated that as long as the fluid remains free of incompatible foreign materials, the only fluid replacement required should be for evaporation losses. The concentrated waste must be collected from the tank and disposed of periodically. For a 4 person household installation, the annual waste volume would be about 2500 L. This system could be combined with an incinerator to destroy waste on-site, thus, eliminating collection and pollution. The incinerator furnished for Matthew and Nesheim's demonstration project was plagued with operational problems and use was discontinued. It should be noted that many of the problems associated with the demonstration project should have been overcome by now; however, a synthetic fluid system for a household has a very high capital cost of around $2500, not including an incinerator. Installation costs, including separate plumbing and the space requirement would also be significant. Annual costs include electricity, chemicals, maintainence and waste removal or treatment and disposal on-site. The high initial cost of these systems and the requirement of trained service personnel make them generally inappropriate for use in households, particularly in northern communities. They would be more cost-effective and appropriate for use in large buildings, camps and public washroom situations.

B.3.6 Treatment Systems. Treatment systems as discussed here are those systems which provide for treatment of wastewater within an individual home or building for the purpose of recycle for toilet flushing. Reuse for all purposes is discussed in more detail in Appendix G. There are three major catagories of recycle for toilets. Some units recycle only within the toilet but unlike recirculating toilets, they usually incorporate some form of biological or physical chemical treatment of the wastewater. Compact, self-contained digesting toilets are one type that are commercially available. The other catagories of recycle use wastewater from other sources, either all of the household wastewater or only the greywater from laundry and bathing and perhaps the kitchen. The level of treatment required for recycle need not meet drinking or body contact standards; however, the liquid must be aesthetic and it should be disinfected. The method of treatment will depend upon the type of wastewater that is being used for recycle, the most complex systems being required for those that accept all household wastewater. Reuse of wash water only has been the most commonly proposed system (Bailey et al, 1969). This has been demonstrated by Cohen and Wallman (1974) and McLaughlin (1975). These researchers estimated the capital cost of their prototype household system at $400. and $500. respectively; however, a commercially available unit costs approximately $2500 plus installation. The treatment system consists of course straining, chlorination, filtration and storage. Operating costs are estimated at $45. per year primarily for the replacement of filter cartridges. Some operating responsibilities must be borne by the homeowner for any recycle system. Milne (1976) suggested that rather than using a conventional toilet with a tank, the toilet could be selected to reduce or eliminate the need for treatment before the reuse of wash water.

The installation of a recycle system requires space for the holding tanks and treatment system and a separate plumbing system, the cost of which will be site-specific. Because of the relatively fixed initial cost such a system would be more cost-effective where it was used to service a number of toilets, such as in a hotel, school or apartment building. Some make-up water may be required initially and periodically. If water conservation devices are used which reduce the greywater volume, then a low water use toilet may also have to be used. In any case, the lowest cost system may be some combination of low water use toilet in conjunction with reuse.

B.4 Economic Analysis

Economic analysis can indicate the lowest present value of various alternatives. However, assumptions must be made in the capital costs and operating requirements as well as life, interest rate, and other factors. Also, non-economic considerations such as aesthetics, user convenience and acceptance are not included but must be considered along with the strict economics. In this analysis, other possible benefits such as the effects on sewage collection and treatment systems are not directly considered, but the unit cost for water and sewer service which is used should incorporate these factors.

Not all toilets are appropriate or practical for some applications. For example, the mechanical seal toilet can only be installed directly over a holding tank and a large recycle unit may not fit into some buildings. In the economic analysis which follows the installation cost assumed is for conditions where installation is practical and normal. Costs for a particular building can be very different, particularly for the retrofit situation. Also, in some cases the individual may install a water conservation device at no apparent cost, whereas, in this analysis, installation by a tradesman is usually assumed. Capital costs and operating requirements utilized are for a specific model or a composite of a number of available products. The costs used are not for any particular northern location, therefore, where transportation or local conditions would significantly affect the installed cost of the alternatives, a site-specific analysis should be carried out. In fact, a site-specific analysis should usually be carried out since the economic analysis presented here serves only to illustrate the procedure and indicate typical results.

Table B-4 summarizes the capital and installed costs and operating requirements for 25 toilet alternatives. The general present value equation for both the retrofit and new installation situations are also presented. These are used to calculate the present value for a typical household at four cost conditions, two piped and two trucked, for the retrofit case. The alternatives are ranked in order of increasing present value for convenient comparison. In most cases, the present value is a function of the water and sewer rate (R_w) times the number of toilet uses per year (U). This can be plotted as in Figure B-2 for the immediate retrofit situation and Figure B-3 for the new installation situation. These figures are valid for all values of R_w x U, therefore, the present values of the alternatives and the lowest cost alternative can easily be determined. For convenience, the water and sewer rate versus R_w x U for various sizes of households and for two and four toilets per capita per day are plotted in Figures B-2 and B-3. In order to present R_w x U values applicable for both piped and trucked cases on the same graph the scale was expanded in the zero to ten range. Since the choices are relatively clear, the scale does not go past a value of 70. To keep the scale large and reduce the clutter not all of the alternatives are included, notably the high cost non-water using alternatives are excluded.

The conditions and unit costs are very different for the piped and trucked systems, therefore, these are discussed separately. The use

TABLE B-4. INITIAL AND OPERATING COSTS AND ECONOMIC ANALYSIS OF TOILET ALTERNATIVES

ALTERNATIVES		INITIAL COSTS			OPERATING REQUIREMENTS		PRESENT VALUE EQUATIONS(3)
		Capital	Installed (I)				
Code	Description	$	Retrofit(1) $	New(2) $	Water (L)	Others	
1	Conventional	100	0(1)	250	20		$I + 122.9\ R_w \cdot U$
1a	- Plastic Bottle	0	0	250	18		$I + 110.6\ R_w \cdot U$
1b	- Weight	2	12	262	14		$I + 86.0\ R_w \cdot U$
1c	- Dual Flush	4	14	264	14		$I + 86.0\ R_w \cdot U$
1d	- Dam	8	18	268	13		$I + 79.9\ R_w \cdot U$
1e	- Replacement Tank	90	140	360	10		$I + 61.4\ R_w \cdot U$
2	Shallow Trap	115	145	265	13.5		$I + 82.9\ R_w \cdot U$
2a	- Dual Flush	119	159	279	9.5		$I + 58.4\ R_w \cdot U$
3	European 9L				9		$I + 55.3\ R_w \cdot U$
4	European 6L	180	280	330	6		$I + 37.0\ R_w \cdot U$
5	European 3L	225	325	375	3		$I + 18.4\ R_w \cdot U$
6	British Dual Flush				6.6		$I + 40.6\ R_w \cdot U$
7	Flush Valve	150	225	300	12.5		$I + 76.8\ R_w \cdot U$
8	Air Pressure	1050	1150	1300	2	2 W/use(4)	$I + 12.3\ R_w \cdot U$
9	Vacuum	1500	2000	2000	1.5	(4)	$I + 9.21\ R_w \cdot U$
10	Mechanical Seal	90	150	270	0.5		$I + 3.07\ R_w \cdot U$
10a	- Holding Tank	225	450	575	0.5		$I + 3.07\ R_w \cdot U$
11	Marine	300	400	500	1		$I + 6.14\ R_w \cdot U$
12	Recirculating	300	400	500	0.2	$0.004/use(4)(5)	$I + (1.22\ R_w + 0.025)U$
13	Packing	750	825	800	0	(6)	$I + 12\ P$
14	Freezing	400	475	450	0	(6)	$I + 12\ P$
15	Incinerating	750	900	850	0	1.2 kWh/use(7)	$I + 7.37\ R_e \cdot U$
16	Compost (large)(7)	2300	3000	2750	0		$I + 0$
17	Compost (small)	750	950	900	0	5 kWh/day	$I + 11200.\ R_e$
18	Synthetic Fluid	2750	3500	3250	0	$75/year(8)	$I + 460 + M$
19	Recycle - greywater	2750	3500	3250	0	$75/year(8)	$I + 460 + M$
19a	Recycle - to toilet(9)	1250	2000	1750	0	$25/year(8)	$I + 150 + M$

	PRESENT VALUE FOR RETROFIT(3)							
	Piped Systems				Trucked Systems			
R_w =	$0.10/1000 L		$1/1000 L		$10/1000 L		$20/1000 L	
R_e =	$0.05/kWh		$0.20/kWh		$0.05/kWh		$0.20/kWh	
U =	5840		5840		5840		5840	
$R_w \cdot U$ =	.584		5.84		58.4		116.8	
Rank	Alt.	PV($)	Alt.	PV($)	Alt.	PV($)	Alt.	PV($)
1st	1b	62	1d	485	10	329	10	509
2nd	1c	64	4	496	12	618	12	690
3rd	1a	65	1e	499	10a	629	10a	809
4th	1d	65	2a	500	11	759	11	1117
5	1	72	1b	514	5	1400	19a	2150
6	1e	176	1c	516	17	1510	5	2474
7	2	193	12	553	8	1868	8	2587
8	2a	193	2	629	19a	2150	14	2635
9	7	270	1a	646	4	2441	13	2985
10	4	302	7	674	9	2538	16	3000
11	12	547	1	718	14	2635	9	3076
12	8	1157	8	1222	13	2985	17	3190
13	17	1510	9	2054	16	3000	18	3960
14	9	2005	19a	2150	15	3052	19	3960
15	19a	2150	14	2635	2a	3570	4	4602
16	14	2635	13	2985	1c	3726	2a	6980
17	13	2985	16	3000	18	3960	1e	7312
18	16	3000	17	3190	19	3960	7	9195
19	15	3052	18	3960	1d	4684	1d	9350
20	18	3960	19	3960	7	4710	15	9508
21	19	3960	15	9508	2	4986	2	9828
22					1b	5034	1b	10056
23					1c	5036	1c	10058
24					1a	6460	1a	12918
25					1	7177	1	14354

NOTES:

(1) Assume that a conventional toilet is presently installed, therefore it must be removed, where necessary, and it has no salvage value.

(2) Includes all power and plumbing hook-ups.

(3) Assume a discount rate of 10% and an economic life of 10 years, therefore the Present Value Factor is 6.144.

(4) Power requirements are not a significant cost.

(5) Chemicals.

(6) Liners, electricity and pick-up.

(7) Electric models.

(8) Does not include qualified inspection and maintenance.

(9) Homemade system with water conserving toilet.

(10) Equivalent to a household of 4 with 4 toilet uses per capita per day.

WHERE:

I = Installed initial cost (Retrofit or New)

R_w = Rate for water and sewer service ($/L)

R_e = Rate for electricity ($/kWh)

U = Number of uses per year

P = Pick-ups per year

M = Present value of annual maintenance

PV = Present Value

Alt. = Alternative

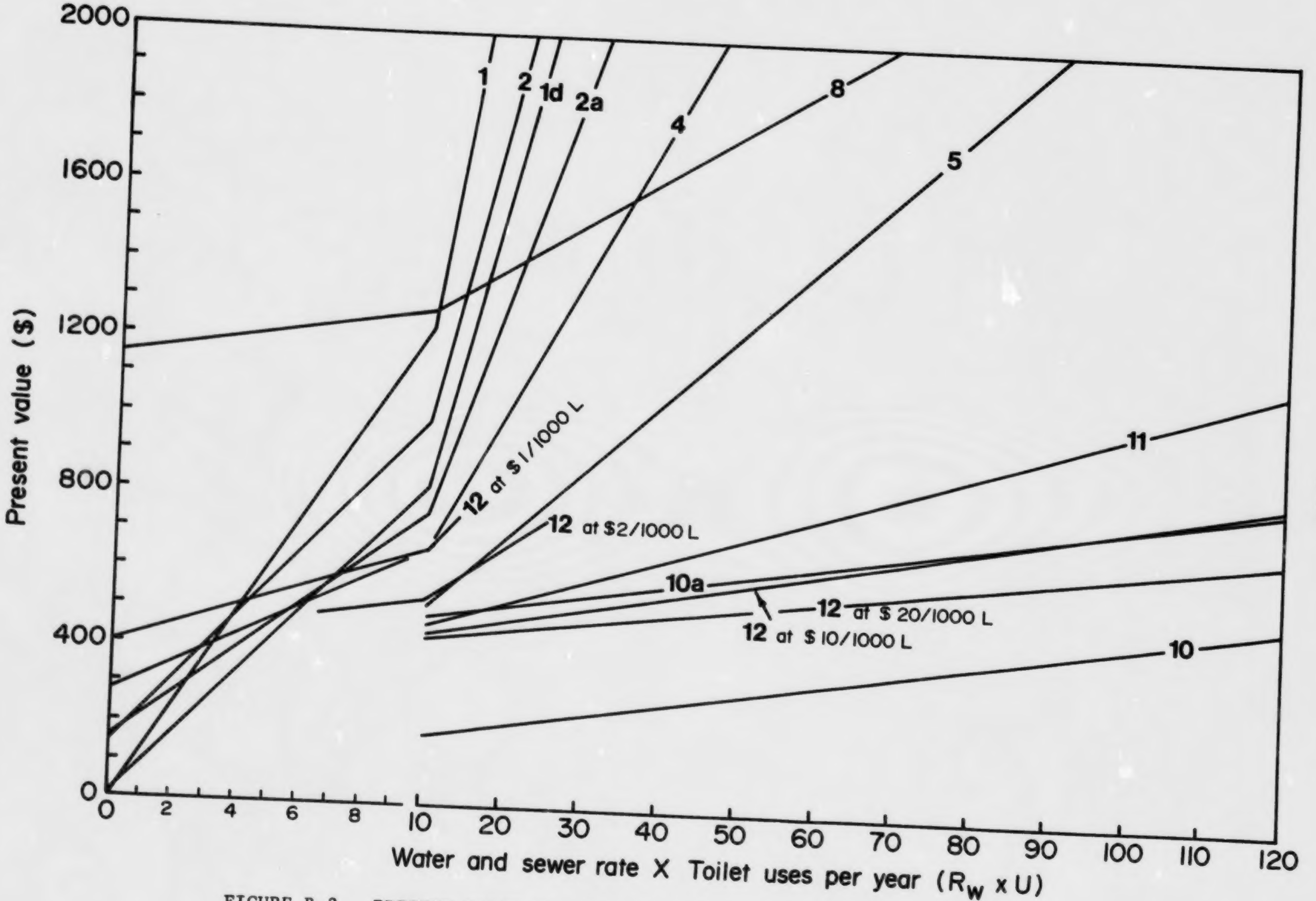


FIGURE B-2. PRESENT VALUE OF TOILET ALTERNATIVES FOR RETROFIT SITUATION

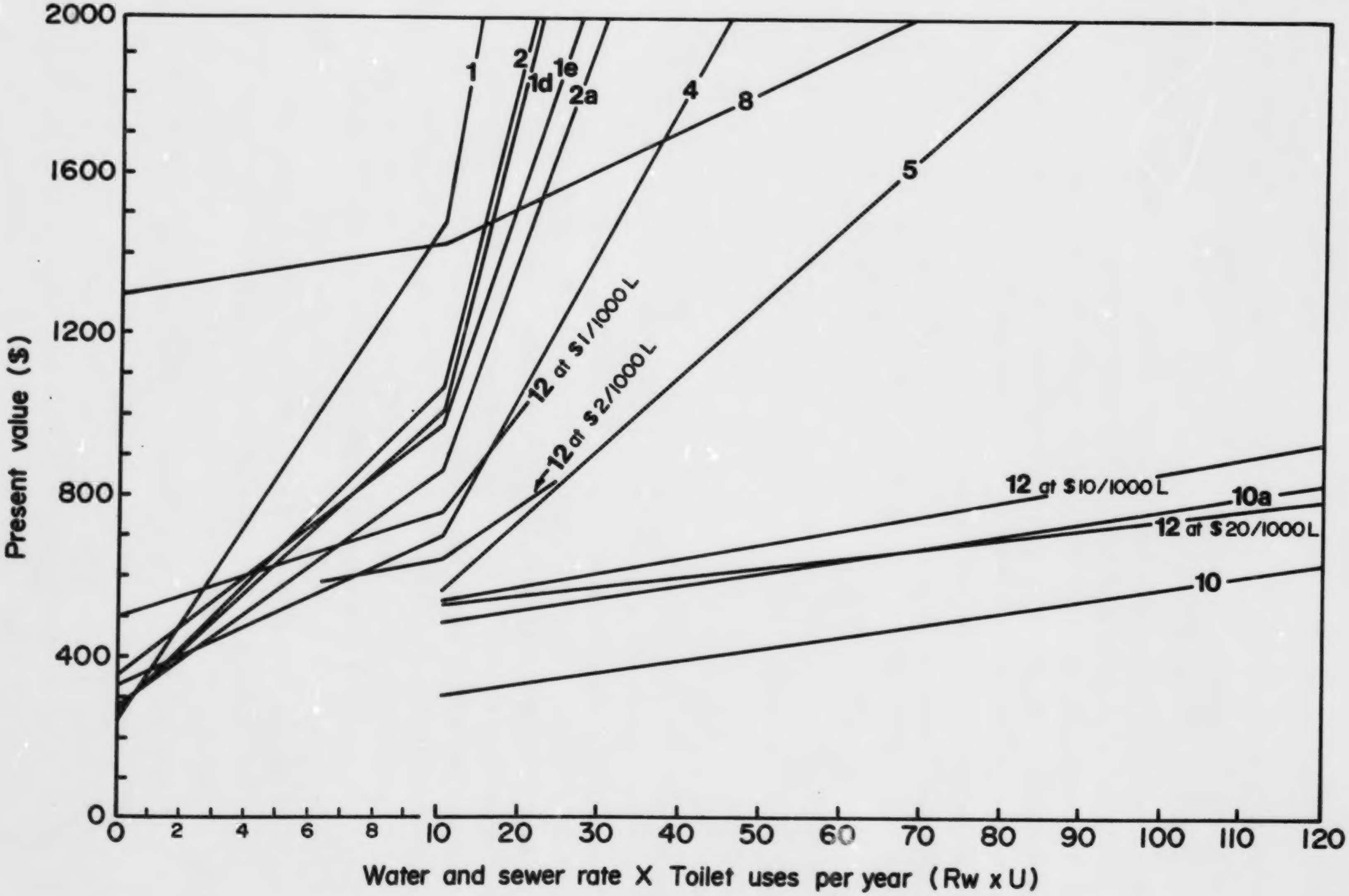


FIGURE B-3. PRESENT VALUE OF TOILET ALTERNATIVES FOR NEW INSTALLATION SITUATION of unit costs to compare alternatives is not usually appropriate for buildings where individual septic fields are used, therefore, this situation is not discussed.

B.4.1 Piped Systems. For piped systems the R_w x U values are less than 10 but are usually less than 5. Table B-4 includes the present values for all of the technically viable alternatives for the immediate retrofit situation for R_w x U value of .584 which represents a water and sewer rate of $0.10/1000 L with 5840 toilet uses per year (16 toilet uses per day or four uses per person for a family of four) and an R_w x U value of 5.84 which represents a high water and sewer rate of $1/1000 L and also 5840 toilet uses per year.

B.4.1.1 Retrofit situation. From Table B-4 and Figure B-2 it can be seen that only for R_w x U values less than 0.5 is it economical to do nothing or perhaps try one of the conventional toilet modification devices. All modification devices, with the exception of the replacement tank are approximately equal to the do nothing alternative at the R_w x U value of .584. For R_w x U values between 1.0 and 6, the lowest alternative is the toilet dam (1d); however, the other low cost conventional toilet modifications, weight (1b) and dual flush (1c), as well as the replacement tank (1e), shallow trap with or without a dual flush (2 and 2a) and the European 6 L (4) are all quite close and the choice is still not very critical. For example, at R_w x U value of 5.84, as tabulated in Table B-4, the present value of the toilet dam device is $485. which is a total present value saving of $232. or an equivalent annual saving of $38/a ($232 ÷ 6.144) compared to a conventional toilet. The annual savings with the other alternatives are: weight ($33); dual flush ($33); replacement tank ($35); shallow trap with dual flush ($35); and European 6 L ($36). Given the much higher investment required for the last three alternatives the choice is clearly to install any one of the conventional toilet modifications.

For R_w x U values greater than six, replacement of the existing conventional toilet is warranted. The lowest cost, fresh water toilet is the European 6 L (4) but when water and sewer rates become over $1.30/1000 L, the recirculating toilet (12) is the most cost-effective alternative. For example, at R_w x U value of 11.68 (\$2/100 L x 5890) uses per year), the present value of the recirculating toilet is \$560 which is a total present value saving of \$875 or an equivalent annual saving of \$142/a compared to a conventional toilet. The annual savings with other alternatives would be: European 6 L (\$118); replacement tank (\$94); and toilet dam (\$79). Although the economics at this rate favours the recirculating toilet, it has the highest capital cost and user operating requirements and probably the lowest user acceptance compared to these other alternatives. Also, many people would only go as far as the installation of one of the inexpensive conventional toilet modifications despite the greater overall savings with the European 6 L toilet, \$118/a versus \$79/a. Although the replacement tank is more cost-effective than the toilet dam, the difference of only \$15/a is not large and this alternative would not be very attractive to most people.

Therefore, for the retrofit case the conventional toilet modification devices are economic for all toilets. At high water and sewer rates and/or high usage, the replacement of conventional toilets should be seriously considered.

B.4.1.2 New installation situation. From Figure B-3 it can be seen that a conventional toilet should only be installed for R_w x U values less than 0.5. For R_w x U values between 0.5 and 2.5 a shallow trap toilet with or without a dual flush device or a conventional toilet with one of the simple conventional toilet modifications could be installed with little loss in economic efficiency. For R_w x U values greater than 2.5, which is only 6.8 uses per day at \$1/1000 L, the European 6 L toilet should be installed although at high rates and/or uses the recirculating toilet is slightly more economical. For example, at a R_w x U value of 5.84 (\$1/1000 L and 16 uses per day) the present values of the European 6 L and the conventional toilet with a toilet dam are \$546 and \$735, respectively, a difference of \$189 or \$31/a. At higher rates or usages, te European 6 L becomes even more attractive and its use appears to be warranted.

B.4.2 Trucked Systems. For trucked systems the R_w x U values are greater than 15 but usually greater than 20 and could go as high as 225 for a large household. Table B-4 includes the present value of all the toilet alternatives for the immediate retrofit situation for R_w x U value of 58.4 representing a typical water and sewer rate of $10/1000 L and 5840 toilet uses per year (16 uses per day or four uses per capita for a family of four) and a R_w x U value of 116.8 representing a relatively high water and sewer rate of $20/1000 L and also 5840 toilet uses per year.

B.4.2.1 Retrofit Situation. From Table B-4 and Figure B-2 it can clearly be seen that conventional toilets, even with either of the modifications, are very uneconomical and therefore could be replaced immediately with a savings. The mechanical seal toilet (10) is always the lowest cost retrofit alternative; however, it can only be used if located directly over the holding tank, which would be uncommon for a retrofit situation. The installation of a separate small holding tank in conjunction with a mechanical seal toilet (10a) may be feasible in some situations but this is more complex and expensive than the installation of a recirculating toilet (12). The same applies to the marine toilet (11). The lowest cost tank flush toilet is the European 3 L (5). It has a cost two to three times that of the recirculating toilet but for some it will be the most aesthetic of the alternatives with reasonably low present values. The small compost toilet is economically attractive where electricity rates are low, less than $0.05/kW·h, and water and sewer rates are very high. If a recycle system to the toilet only could be installed for a capital cost of $1250 it would be more economical than a conventional toilet but is still over three times the cost of a recirculating toilet. Other toilet alternatives such as the vacuum system, large compost and the synthetic fluid have very high present values, primarily due to high capital costs, and are not plotted in Figures B-2 and B-3.

At a R_w x U value of 58.4, Table B-4 indicates a present value for the recirculating toilet of $618 which is a total present value saving of $6559, or $1068/a, over a conventional toilet. Similarly, the savings over a conventional toilet with a dam are $4684 or $662/a and savings over the European 3 L toilet are $782 or $127/a. The recirculating toilet is clearly the most economically practical alternative for the retrofit situation; however, some people may still prefer a European 3 L toilet due to its conventional appearance and lack of routine operating requirements. At higher water and sewage rates the recirculating toilet becomes even more attractive and very substantial savings would be lost in buildings where they were not installed. At lower usages, for example at eight uses per day (equivalent to two uses per capita per day for a household of 4), and $10/1000 L the present value savings over a conventional toilet with a dam and a European 3 L toilet are $2351 and $353 respectively, which is equivalent to $383/a and $58/a, respectively.

Some alternatives have a lower unit cost when used in a multiple installation, for example, the air pressure and vacuum toilets. However, at a water and sewage cost of $10/1000 L the present value of the operating costs alone for these alternatives would be $718 and $538, respectively, compared to a total present value of $618 for the recirculating toilet. Therefore, the air pressure or vacuum toilet alternatives could never be more economical than the recirculating toilet. Toilets that do not use any water or power and have zero operating costs, such as the large compost toilet, must have a installed cost of less than $618 to be more economically attractive than the recirculating toilet. Present models cost far more than this amount and it may be impractical to expect new technology to reach this goal unless other benefits, such as reduced pollution load, are significant.

In some cases, chemical costs for the recirculating toilet will be higher due to high transportation costs. For the retrofit situation and 5840 toilet uses per year with a water and sewage cost of $10/1000 L and chemical costs double the cost assumed in the analysis, the present value would be $763 compared to $618. Thus, the recirculating toilet would still have the lowest cost of the practical alternatives.

B.4.2.2 New installation situation. The economics of the new installation situation is similar to the retrofit situation. From Figure B-3, it can be seen that wherever possible a straight drop, mechanical seal toilet is the least cost alternative. If installation is not possible or practical then a recirculating toilet should be installed. The most economic flush tank toilet considered was the European 3 L toilet, but even it has a present value which is about double that of the recirculating toilet.

Table B-5 Toilet modification alternatives

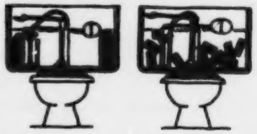
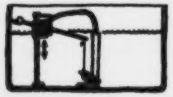
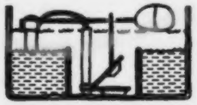
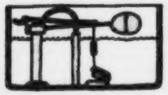
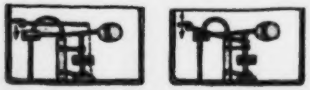
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Bricks or plastic bottles 	Bricks or plastic bottles filled with water and weighted with small stones or completely filled with sand or gravel are inserted into the toilet tank. For each flush they displace and, therefore, save water equal to their volume.	Inexpensive, easily installed homemade devices usually consisting of discarded household items. If inadequate flushing results, plastic bottles can be cut reducing the size until the toilet flushes satisfactorily.	Bricks deteriorate in water and particles will clog water jets and lodge under the flush valve causing a continuous leak. They can also crack the tank if dropped or fall over, and multiple bricks will inhibit the flow of water around them. Bricks are not recommended. Plastic bottles can shift and interfere with the flushing mechanism and if filled with sand and not properly sealed, escaping sand can lodge under the flush valve resulting in a continuous leak.	None	Depends on size. Two bricks or two plastic bottles will save approximately 2 litres or about 10% per flush.	Low to none for homemade.	None
Improved float assemblies 	Replaces existing conventional float ball and fill valves, allowing water levels to be lowered and adjusted to use exactly the minimum amount of water necessary for efficient flushing.	Improves flushing efficiency and some will facilitate the detection of leaks. Potentially more durable than conventional replacement equipment due to less wear. Valve on leak signaling type is always in fully open or closed position, therefore, is quieter than slow closing conventional ballcocks.	Water savings are essentially limited to the elimination of leaks. Slightly higher cost than conventional replacement equipment.	Connects to toilet water line.	Depends on existing mechanism, therefore, savings can vary from none to significant. Very little data is available on how much water is lost due to leakage.	$6. - $10.	None
Dams 	Plastic or metal wall is inserted into toilet tank in a verticle position and sealed against the sides and bottom of tank. Some types encircle the flush valve outlet, but all prevent the lower portion of water from draining out of the tank when the toilet is flushed.	Easy to install and will reduce water usage more than homemade devices. Will not interfere with static head or flush mechanism. Types made of metal and rubber are potentially more durable than those made of plastic.	Some types are not adjustable to allow only the minimum amount of water for efficient flushing to be released. Due to the age and design of some toilets they may not give an adequate flush.	None	Saves approximately 35% or about 7 litres per flush.	$4. - $8.	None
Weights 	Attached to the ball-chain or rod. After the desired amount of water is flushed the flush handle is released, and the weight immediately forces the stopper back into the flush valve seat, and flow stops.	Nearly as effective as dams in reducing water consumption and can be used in conjunction with dams to maximize savings. Can be homemade.	Negates the normal operation of the toilet flush mechanism and user must hold down handle for both solid and liquid waste until the desired quantity of water has been released. Commercial types have no advantage over homemade variaties.	None	Saves an average of approximately 30% or about 6 litres per flush.	$.80 - $8. None for homemade..	None
Dual - flush mechanisms 	Single action type can be a counterweight, floating cylinder or air bleeder mechanism which manipulates the flush valve stopper. When toilet is flushed normally, only a portion of flush water is released. For a full tank flush, the flush handle is held down. Double action types replace existing flush valve assembly. The flush handle moves in one direction for low volume flush (liquid wastes) and in the opposite direction for full flush (solid wastes).	Allow for user choice in flush quantities. Can be used in conjection with dams.	Single action types require handle to be held for full tank volume flush. Air bleed types could become clogged with water deposits or dirt. The double action flush mechanism is difficult to install and since it is not adjustable, it may not give an adequate flush in all toilets.	None	Saves approximately 30% for low volume flush resulting in an average total saving of approximately 30% or 6 litres per flush.	$3. - $15.	None
Replacement tanks	Mounts on existing toilet bowl replacing the whole reservoir tank with a pressure tank cartridge and cover. Water entering the empty tank compresses the air inside, stopping when water and air pressure are equal. When toilet is flushed, compressed air and gravity force water into the bowl.	Uses about half the water used by a conventional toilet tank.	Expensive and more difficult to install than other devices. Somewhat noisy at high pressure and may not work adequately on systems with water pressure less than 240 kPa.	Mounts on standard toilet bowl and must be connected to water line.	Uses approximately 9.5 to 11.5 litres per flush, therefore, saves approximately 50%.	$65. - $95.	None

Table B-6

Supplier	Conventional flush toilet modifications				
	Damming devices	Improved float assemblies	Dual flush mechanisms	Weighting devices	Others
American Standard 80 Ward Street Toronto, Ontario M6H 4A7 Tel. (416) 534-3521		●			
Aqua-Aid of Canada Ltd. 17 Main Street, North Newmarket, Ontario L3Y 3Z6 Tel. (416) 898-4441			●		
Aqualine Products Ltd. 1677 Aimco Blvd. Mississauga, Ontario L4W 1H7 Tel. (416) 625-9301			●		
3-B Manufacturing and Supply Co. 6969 Worthington-Galena Rd. Worthington, Ohio U.S.A. 43085			●		
Business Marketing Systems 223 Thousand Oaks Blvd. Oaks, California U.S.A. 91360	●				
Fluidmaster, Inc. P.O. Box 4264 1800 Via Burton Anaheim, California U.S.A. 92803 Tel. (714) 774-1444		●			
G&E Products Inc. 2082 S. Grand Avenue Santa Ana, California U.S.A. 92705	●				
Geberit Manufacturing, Inc. Michigan City, Indiana U.S.A. 46360					*●

* Replacement tank

Table B-6 (cont') Conventional flush toilet modifications

Supplier	Damming devices	Improved float assemblies	Dual flush mechanisms	Weighting devices	Others
Global America Corp. P.O. Box 246 El Toro, Calif. U.S.A. 92630 Tel. (714) 533-4400			●		
Jegco, Inc. P.O. Box 8482 Emeryville, California U.S.A. 94608 Tel. (415) 655-5079				●	
Jenkins, S.M., Inc. "Ecology Helper" 106 West Jefferson Street Falls Church, Virginia U.S.A. 22046 Tel. (703) 532-6542				●	
Merwin Manufacturing, Inc. Post Office Box 509 Dunkirk, New York U.S.A. 14048 Tel. (716) 366-4103	●				
Ny-Del Corporation 740 E. Alosta Avenue Glendora, California 91740 Tel. (213) 335-2213	●				
Savway Dual Flush Co. 930 Clarkson Avenue Brooklyn, New York U.S.A. 11203			●		
Sexauer, J.A., Inc. 10 Hamilton Avenue White Plains, New York U.S.A. 10601 Tel. (914) 682-8600					*●

*Toilet leak detector pellets

Table B-6 (cont')

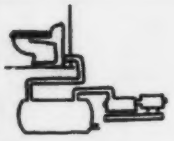
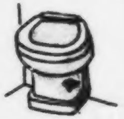
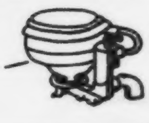
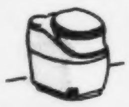
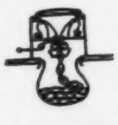
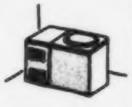
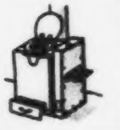
Supplier	**Conventional flush toilet modifications**				
	Damming devices	Improved float assemblies	Dual flush mechanisms	Weighting devices	Others
Water Control Products/N.A., Inc. 1100 Owendale, Suite E Troy, Michigan U.S.A. 48084					*●
Watersavers, Inc. P.O. Box 22326 Cleveland, Ohio U.S.A. 44122 Tel. (216) 292-2550	●				
Water Wizard, Inc. P.O. Box 184 Croydon, Pennsylvania U.S.A. 19020 Tel. (215) 946-5702	●				
Whedon Products, Inc. Box U, Station A 2074 Park Street Hartford, Conn. U.S.A. 06106 Tel. (203) 232-9877	●				
Zin-Plas Corporation 1007 North Division P.O. Box Q Grand Rapids, Michigan U.S.A. 49501 Tel. (616) 454-9441				●	

* Flushmate replacement toilet tank

Table B-7 Toilet alternatives

	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Outhouse	Wastes biodegrade in pit and seep into soil. Pit gradually fills and outhouse must be moved.	Easy, inexpensive, no pipes, no water required, no moving parts.	Unpleasant odors, cold in winter, inconvenience of access, can contaminate water sources. Not applicable for use in developed communities or in areas with permafrost. Must be periodically moved to new site.	None	None	$0-$150	$0
Bucket	Wastes drop directly into bucket with deodorizing chemical or into plastic "honeybag." Bucket is dumped and recharged periodically or "honeybag" is removed for pick-up and replaced with fresh bag.	Inexpensive, simple, no water required, no moving parts.	Little more than an indoor outhouse. Removal of wastes from the building and the collection and disposal is often unsanitary. Collection should be 5 times per week.	Vent only.	None	$25-$100	Varies, but is low. Some require chemicals and/or plastic bag inserts (5c/bag).
Conventional	Wastes are syphoned through a trap by a sudden rush of water from the tank reservoir.	Sanitary, odorless, relatively easy to repair and inexpensive to buy.	Uses large quantities of water to transport small quantities of wastes. Ultimate disposal of sewage is a problem. Requires pressure water supply and piped gravity sewage collection system.	9.5mm water 75mm waste	15-30 litres/flush avg. 20 litres/flush	$60-$240 Some as high as $500	Depends on cost of water; family of four would use approximately 400 litres per day for flushing.
Shallow trap	Same as above, except has a shallower trap and smaller reservoir tank.	Same as above, except toilet water use is approximately 33% less than conventional.	Same as above except uses less water.	same as above	13-16 litres/flush avg. 14.5 litres/flush	$80-$200	Same as above except family of four would use approximately 290 litres per day for flushing.
European 6L	Wastes are syphoned through a trap by a sudden rush of water. Has shallow trap and smaller reservoir tank than conventional. Models with 9 litre flush available.	Sanitary, odorless, toilet water use is approximately 70% less than conventional.	Sewer pipe connection is centred at back of toilet therefore may present retrofit problems. Performance not as good as conventional North American toilets, particularly for non-human waste materials.	9.5mm water 75mm waste	6 litres/flush	$170-$225	Depends on cost of water; family of four would use approximately 120 litres per day for flushing.
European 3L	Same as above with smaller trap and water mirror.	Same as above, except toilet water use is approximately 85% less than conventional.	Same as above but connection must be to a ground tank, not a piped sewage collection system. Several recommendations for installation with respect to sewer pipe size, slope and maximum distance. These may inhibit use as retrofit.	same as above	3 litres/flush	$220	Same as above except family of four would use approximately 60 litres per day for flushing.
Flush valve	Handle releases high velocity water injection producing swirl effect to syphon wastes through a trap.	Eliminates need for bulky reservoir tank and generally have a shorter pre-fixed cycle and quicker recovery time. Toilet bowl is well cleaned by flushing action.	Depend on water line pressures and will be affected by pressure changes due to use of other fixtures. Requires 25 mm water service line, therefore, is not applicable for household use.	25mm water 75mm waste	8.5-16 litres/flush	$100-$175	Depends on cost of water; family of four would use approximately 170-320 litres per day for flushing.
Air pressure	Wastes and flush water drop from bowl into a secondary chamber where an air charge is induced to pressurize and eject water and waste materials into discharge line.	Uses little water and will retrofit into conventional plumbing system. Same air compressor can be used on multiple toilet installation. Does not have reservoir tank.	Requires air compressor or compressed air bottle and operation is relatively complex. High capital cost plus power requirement for air compressor or recharging of air bottle.	9.5mm water 75mm waste compressed air at 410 kPa or electricity for compressor.	2 litres/flush	Vitreous China $600-$675 Stainless Steel $800-$875 Air Compressor $400	Cost of water and electricity. Family of four would use approximately 40 litres per day for flushing and 15 kW-h per year to run compressor.

Table B-7 Toilet alternatives (continued)

	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	**Operating**
 **Vacuum**	Vacuum toilet connected to special valve mechanism and discharge piping. Utilizes an air pressure differential created by partially evacuating the air from the pipe network to transport slugs of wastewater through small diameter piping to central collection vacuum tank.	Uses little water and toilet does not have reservoir tank. Collection system uses small diameter plastic pipe which can be installed relatively independent of grade. Vacuum mains can be laid in same trench as watermains and have less heat loss due to lower volumes of fluid transported. Can be connected to multiple units within the same building or community.	Relatively complex operation and high capital cost. System requires back-up pumps and power. Installation requires qualified personnel.	9.5mm water 38mm waste electricity at collection tank for vacuum pump	1 litre flush	Individual bu'lding approx. $3300 Community systems vary.	Cost of water and electricity to run vacuum pump.
Mechanical seal 	Pedal or handle opens valve in bottom of bowl and actuates swirl of fresh water to rinse bowl. Also, portable models with detachable holding tank for dumping of waste.	Fresh water flush but very low water use. No chemicals or recirculating. Can be used as portable unit with holding tank.	Sewer lines will clog due to low volume flush, therefore should only be used when there is a relatively straight drop into a holding tank. Portable unit must be dumped and recharged.	Varies from none to 9.5 mm water and 75 mm waste to holding tank.	.5 litres/flush	$75-$175	Depends on cost of water. Family of four would use about 10 litres per day for flushing. Portable model requires deodorizing chemical.
Marine 	Hand or electric pump brings water into bowl. Valve is turned, same pump ejects wastes. Can pump wastes uphill.	Relatively low water usage. Can pump its waste uphill. Pumps its own water and could be used as a recirculating toilet.	Clogs relatively easily. Relatively complicated to use. Power consumption for electric models.	19 mm water 38 mm waste 120V or 12V for electric models	1 litre/flush, electricity for some models	$100-$400	Depends on cost of water and nominal power for electric models.
Recirculating 	Hand and/or electric pump swirls filtered, chemically treated wastewater from holding chamber to flush and rinse bowl. When full, unit must be dumped and recharged with chemical and water. Portable or fixed models available.	Uses very little water. Fixed units can be used with conventional plumbing; usually discharge to holding tank.	Relatively complex and some larger commercial models expensive to buy. Requires dumping and recharging with chemicals every five days for family of four.	Varies from no hookups to 120V or 12V; 9.5 mm water; and/or 75 mm waste to holding tank or sewer.	0.2 litres fresh water/flush, electricity for some models	$90 (portable) $350 (fixed) Up to $3000 for public washroom system.	Depends on cost of water and nominal power for 12V elecric models. Family of four would use 4 litres per day. Chemical cost approx. $.50 per charge or $0.10 per day for a family of four.
Packaging 	Wastes drop into plastic lined bowl. The continuous tube of plastic is drawn down through the bowl and is heat sealed to form a series of "sausages." Plastic bag under toilet collects "sausages" which must be periodically removed.	Handling of waste is improved. Odors and breakage of bags is minimized by isolating small quantities of waste in separate "sausages."	Expensive to buy and use. Requires plastic liners, collection bags and electricity. Collection and ultimate disposal of bags must be organized and can create problems.	120V electricity	Electricity, no water	$500-$1000	Manufacturer claims electrical consumption is 1 kW·h per 3400 uses. Costs for regular changing of collection bags and liners.
Freezing 	Wastes drop into plastic bag in a small freezing compartment. When full, bag is removed for pick-up and replaced with new bag.	Freezing prevents decomposition, odors and handling of waste is much easier and more sanitary and acceptable.	Relatively expensive to buy, requires plasticized bags, and electricity. Power failure or defrosting reactivates decomposition. Collection and ultimate disposal of bags must be organized and can create problems.	120V electricity	Electricity, no water	Approx. $400	Costs for 120 watt compressor and collection bags.
Incinerating 	Wastes are incinerated in timed cycle after each use. Ash must be removed periodically. Models use electricity or gas.	No liquid waste generated and very little ash to dispose of. Reduces pollution.	Uses considerable energy. Some models require use of paper bowl liner with each use. Relatively complex mechanism. Must be vented.	120V or 220V (recommended) electricity, or optional 9.5 mm gas with 120V or 12V optional; 100 mm vent	Electricity or gas, no water	Approx. $650 - $1000	Depends on cost of energy. Uses approx. 0.1 cubic meters gas or 1 kW·h per use. Also, bowl liners and odour control catalyst.

→

Table B-7 Toilet alternatives (continued)

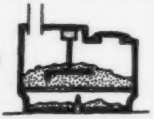
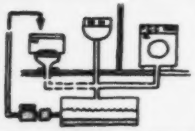
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Composting (large)	Kitchen garbage and human wastes are digested by microorganisms, producing fertiliser.	End product, compost, can be used as fertiliser. Reduces pollution. No water, sewer or electrical hookups required. No moving parts. Little maintenance.	High initial cost for unit and installation. Unit is very large, requiring considerable basement space.	150 mm vent	none	$1500-$2500	None, some value created in fertiliser.
Composting (small) 	Same as above, except compact and uses forced air circulation and heat to speed process.	No water or sewer hookups required. Unit is relatively small and can be installed in conventional washroom. End product, compost, can be used as fertiliser. Reduces pollution.	Expensive to buy and relatively complex to maintain and operate properly. Requires significant energy input and can not handle shock loading of organic and liquid wastes.	120V electricity 100 mm vent	Electricity, no water	$500-$1000	Power requirement of 1.2 to 8.75 kW·h per day for fan and heating element.
Synthetic fluid	System utilises special chemical fluid or mineral oil as flushing medium. Waste materials settle out in holding tank and fluid is filtered and recycled to conventional toilet. Waste must be pumped out about once a year.	Utilises conventional toilet and plumbing but no water. Can be used in conjunction with an incinerator to destroy concentrated wastes. Applicable for multiple units such as camps or public washrooms.	High initial cost for unit and installation. Requires significant space and is relatively complex. Requires replacement of lost fluid and addition of odor control chemicals. Energy requirement for pumps and incinerator, if used, otherwise waste must be pumped out for disposal.	Connection to recycle system 9.5 mm water 75 mm waste Electricity for recycle system	Electricity, no water	$2500-$5000	Costs for replacement fluid, odor control chemical and power for electric motors.
Treatment systems (recycle) 	Recycle of treated and filtered toilet and/or other wastewater for toilet flushing. Sludge in tank must be pumped out every year or two.	Uses little or no fresh water Some will accept wastewater from other fixtures.	High maintenance and capital cost. Requires filters, disinfectant, dye, pumps and electrical power.	Connection to treatment/recycle system 9.5 mm water 75 mm waste electricity for treatment and recycle system	Electricity, uses wastewater	$2500-$5000	Cost for disinfectant, dye, filters and electricity.
Urinals	Handle releases high velocity water injection syphoning liquid wastes through a trap.	Low volume flush models use very little water compared to conventional toilet. Uses conventional plumbing. Commonly used in public washrooms.	Relatively expensive addition to household washroom. Only handles liquid waste. Low consumer acceptance due to institutional and public image.	9.5 mm water 50 mm waste	4-15 litres/use	$75-$150	Depends on cost of water.

Table B-8

Supplier	Toilet															Treatment systems	Urinals
	Reduced flush		Low water use						Non-water using								
	Shallow trap	Flush valve	European	European 3 litre	Air pressure	Vacuum	Marine	Mechanical seal	Recirculating	Bucket	Incinerator	Compost	Synthetic fluid	Freezing	Packaging		
Aera-Filt Systems, Inc. P.O. Box 567 Lafayette, Indiana U.S.A. 47901 Tel. (317) 742-4206																●	
American Standard 80 Ward Street Toronto, Ontario M6H 4A7 Tel. (416) 534-3521	●																●
Aquasaver Inc. 7920 Belair Rd. Baltimore, MD. U.S.A. 21236 Tel. (301) 483-1331 Greywater treatment and recycle to toilets																●	
Ball-Hed Marine Products Co., Inc. 5219 Sangamore Rd. Washington, D.C. U.S.A. 20016 Tel. (301) 652-0559							●	●									
R. Barsloux 966 Knottwood Road S. Edmonton, Alberta T6K 3H7 Tel. (403) 462-6014											●						
Bartle and Gibson Co. Ltd. 7214 Fort Road Edmonton, Alberta T5B 4E8 Tel. (903) 474-8991 Distributors of Kohler products	●																●
Bio Systems Toilet Corp. Ltd. 255 Gladstone Road Hawkesbury, Ontario K6A 2G8 Tel. (613) 632-9502												●					
Borg-Warner Corporation Plumbing Products Div. 201 E. Fifth Street Mansfield, Ohio U.S.A. 44901	●																
Briggs Manufacturing Company P.O. Box 22622 Tampa, Florida U.S.A. 33622 Tel. (813) 871-4811	●																

Table B-8 (cont')

Supplier	Toilet																
	Reduced flush		Low water use						Non-water using								
	Shallow trap	Flush valve	European	European 3 litre	Air pressure	Vacuum	Marine	Mechanical seal	Recirculating	Bucket	Incinerator	Compost	Synthetic fluid	Freezing	Packaging	Treatment systems	Urinals
Canadian Inventer Ltd. P.O. Box 541 Don Mills, Ontario M3C 2T6 Tel. (416) 447-6941												●					
Crane Canada Limited 5800 Cote de Liesse Road Montreal, Quebec H4T 1B4 Tel. (514) 735-3592	●																●
Eljer Plumbingware Wallace Murray Corporation Room 1230 Two Pennsylvania Plaza New York, New York U.S.A. 10001 Tel. (212) 244-8715	●	●															●
Enviroscope, Inc. P.O. Box 752 Corona del Mar, California U.S.A. 92625 Tel. (714) 673-7774			●	●		●		●				●					
Fowler, H.D., Co. Ltd. 119 West Pender Street Vancouver, B.C. V6B 1S5 Tel. (202) 683-2508 Distributor of Microphor products					●											●	
Future Eco-Systems Ltd. 680 Denison St. Markham, Ontario L3R 1C1 Tel. (416) 495-6450												●					
Gerber Plumbing Fixutres Corp. 4656 West Touhy Avenue Chicago, Illinois U.S.A. 60646 Tel. (312) 675-6570	●																
Humumat Ltd. 9403-120 Street Delta, B.C. V4C 2P3 Tel. (604) 588-5955												●					

Table B-8 (cont')

	Toilet																
	Reduced flush		Low water use						Non-water using								
Supplier	Shallow trap	Flush valve	European	European 3 litre	Air pressure	Vacuum	Marine	Mechanical seal	Recirculating	Bucket	Incinerator	Compost	Synthetic fluid	Freezing	Packaging	Treatment systems	Urinals
Jensen Sanitation Systems 1946 East 46th Street Los Angeles, California U.S.A. 90058 Tel. (213) 232-8292									●								
Mansfield Sanitary, Inc. 150 First Street Perrysville, Ohio U.S.A. 44864 Tel. (419) 938-5211						●		●									
Markt & Co. A/S Kirkegt. 6B Oslo 1, Norway														●			
McPherson, Inc. P.O. Box 15133 Tampa, Florida U.S.A. 33614		●															
Mervin Manufacturing, Inc. Post Office Box 509 Dunkirk, New York U.S.A. 14048 Tel. (716) 366-4103						●											
Microphor Division of Harrah Industries, Inc. 452 East Hill Road P.O. Box 490 Willits, California U.S.A. 95490 Tel. (707) 459-5563					●											●	
Monogram Sanitation Products of Canada Ltd. 441 Wyecroft Road Oakville, Ontario L6K 2H2 Tel. (416) 842-1101									●			●					
Multi-Flo, Inc. 500 Webster Street Dayton, Ohio U.S.A. 45401 Tel. (513) 224-7622																●	
Pactosan A/B Box 100 71300 Nora Stad Sweden															●		

Table B-8 (cont')

Supplier	Toilet																
	Reduced flush		Low water use						Non-water using								
	Shallow trap	Flush valve	European	European 3 litre	Air pressure	Vacuum	Marine	Mechanical seal	Recirculating	Bucket	Incinerator	Compost	Synthetic fluid	Freezing	Packaging	Treatment systems	Urinals
Pure Way Corporation 301-42nd Avenue East Moline, Illinois U.S.A. 61244 Tel. (309) 755-2116								●									
Raritan Engineering Company 1025 North High Street Millville, New Jersey U.S.A. 08332 Tel. (609) 825-4900						●											
Research Products/Blankenship of Canada Ltd. 18 Canso Road Rexdale, Ontario M9W 4L8 Tel. (416) 244-8824											●						
Sanitation Devices, Inc. 935 St. Peter Street New Orleans, Louisiana U.S.A. 70116													●				
Sanitation Equipment Limited 1081 Alness Street Downsview, Ontario M3J 2J1 Tel. (416) 661-2560								●	●								
Sarmax Corp. 2207 S. Colby Ave. Los Angeles, California U.S.A. 90064													●				
Sea-Lawn Products Co. 365 East Park Avenue Long Beach, L.I., N.Y. U.S.A. 11561 Tel. (516) 431-3360											●						
Simpsons-Sears Limited 222 Jarvis Street Toronto, Ontario M5B 2B8 Tel. (416) 861-9111	●																
Stello Products Inc. 840 West Hillside Spencer, Indiana U.S.A.										●							

Table B-8 (cont')

Supplier	Toilet																
	Reduced flush			Low water use						Non-water using							
	Shallow trap	Flush valve	European	European 3 litre	Air pressure	Vacuum	Marine	Mechanical seal	Recirculating	Bucket	Incinerator	Compost	Synthetic fluid	Freezing	Packaging	Treatment systems	Urinals
Te-Be Elprodukter Pack 34 561 01 Huskvarna Sweden														●			
Techniques Agricoles Modernes 1, Rue du Bac Paris 7, France										●							
Traco Manufacturing Ltd. 7041-Farrell Rd., S.E. Calgary, Alberta T2H 0T3 Tel. (403) 253-2231 Distributor of Thetford products								●	●								
Tweed Steel Works Eastern Ltd. P.O. Box 340 Tweed, Ontario K0K 3J0 Tel. (613) 478-2126										●							
Vacusan Systems Limited 117 Dolomite Drive Downsview, Ontario M3J 2N1 Tel. (416) 661-5721						●											
Waterlo 41, Rue Censier Paris 5e, France										●							

APPENDIX C

BATHING ALTERNATIVES

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C. BATHING ALTERNATIVES

Bathing is the second largest consumer of water in the household and the largest, exclusive of heating and cooling, consumer of household energy. An average of 26.0% of the total water used inside the typical home is for bathing and 3.7% is used in the lavatory sink (Table 2). Approximately 50% to 75% of this is heated water (Nelson, 1977) to obtain a bathing water temperature of approximately 40°C (Muller, 1975). For a household of four on a piped water and sewer system this represents an annual bathing water usage of 85,400 L (59 L/person·d). If the portion of total household water use for bathing remains constant, this same household of four on a truck system would use 36,100 L/a (25 L/person·d) for bathing purposes, considerably less than the piped system. As mentioned in previous sections, the reduced water demand for those on the trucked system could be attributed to a general awareness of a limited water supply. Water usage is, therefore, moderated and wasting of water is reduced. Also, the internal water pressure is less than that received with a piped system, resulting in less water flow at fixture outlets. This indicates that although the assumption of a constant breakdown of household water use is reasonable for estimating purposes it is likely that the actual household water use percentages will vary somewhat. However, it is very probable that bathing will remain a major water and energy consumer.

It has been estimated that 60% of the bathing in homes with both a shower and tub is done in the shower with the remaining 40% used for tub baths (Bailey et al, 1975; Howe and Vaughan, 1972; Wallman, 1972). However, these average values do not represent any particular household since some individuals may prefer either showering or tub bathing all of the time.

The amount of water used for bathing can be reduced through changes in user habits and/or by the use of water-saving hardware. Milne (1976) observed that water saving products for bathing and personal hygiene generally fall into three categories: either they reduce the flow rate required by conventional equipment; or they improve temperature control; or they modify the fixtures volumetric capacity. A summary of the various fixtures available for bathing is presented at the end of this Appendix in Table C-2, followed by a shower devices supplier list in Table C-3.

C.1 Lavatory

By definition the lavatory is a fixed bowl or basin with running water and a drain pipe which is used for washing. It facilitates such water using activities as washing hands and face, brushing teeth, shaving and washing hair. While the water used in performing these functions only consumes 3.7% of the fresh water used in the home, much of it is wasted when faucets are left running unnecessarily. For example, Wentz (1975) indicated that an average of 5.6 L of water are used when a person washes his hands for 30 seconds under a free-flowing faucet but if the bowl is filled for hand washing only approximately 1.9 to 2.6 L of water are used. Ponding water is one of the major water saving tips suggested by the Washington Suburban Sanitary Commission (1972). In addition, Milne (1976) states that sinks which are designed to best fit the function served without excess volume save the greatest amounts of water. Regular maintenance of faucets and drain plugs combined with an adjustment in user habits will reduce the waste of water. Several suggestions in both these areas are contained in Appendix G. Also, discussed in Appendix F, Miscellaneous Water Conservation Alternatives, are several types of faucets and devices with flow or temperature control which will reduce water consumption.

C.2 Bathtubs

The quantity of water used for tub bathing will vary with the size and shape of the bathtub and the individuals personal washing style. These two factors combine to make it difficult to estimate how much water is used for a typical tub bath. Kohler Company (1977) estimated that 115 L of water would normally be required for a tub bath. Milne (1976) calculated that a standard bathtub 1.5 m long filled 25 cm deep would hold about 190 L of water. Based on these quantities, it seems reasonable to assume that a "normal" bath in a "standard" bathtub will require approximately 150 L of water. Larger bathtubs, with or without whirlpool spas, because of their high water consumption and increased energy use would be classified as major water consumers. Multi-person tubs which usually hold at least 600 L of water are in this category, but fortunately, many of these tubs are not drained after each use.

While the quantity of water required for tub bathing is felt to be excessive, there are several advantages of this method of bathing. Because the same quantity of water is used for each tub bath, the duration of bathing will have no effect on the water usage except when the water cools enough to require the addition of more hot water. Also, the rate at which water flows into bathtub has no effect on water consumption. Therefore, conventional plumbing can be used or the tub can even be hand filled where there is no household plumbing. Another advantage is that warm water can be reused or left in the bathtub to recover heat before discharge.

The concept of water conservation as applied to bathtubs usually involves a change in the individuals personal washing style. Appendix G contains a number of useful suggestions with the most logical being that of using less water in the bathtub. Filling the tub 1/4 full is usually sufficient to cover the human body and facilitate personal hygiene. Muller (1976) suggested that the shape of the bathtub could be redesigned to conform more closely to that of the human body to reduce the water required. Bathtubs which are designed to match the function served without excess volume will save water. For example, a bathtub which is designed for bathing with minimal water, and in limited space, from a seated position is the "sitz bath". These tubs are commonly used in Europe and are being introduced into North America by some of the major plumbing manufacturers.

Muller (1975) also suggested that bathtubs should be insulated to reduce heat loss and, therefore, the need to add more hot water to heat up the cooled bath water. Along the same lines, bathtubs could also be made of material with a low specific heat. In recent tests by

Universal Rundle Corporation (Anon. 1978) it was indicated that fiberglass tubs "use" less energy. Their tests were conducted by placing electric heaters in tubs made of enamel steel (vitreous china), fiberglass and cast iron, and filling with 95 L of 42°C water. It was then possible to measure the amount of energy required to maintain the water temperature. According to their results, enamel steel required 50% more energy than did fiberglass and cast iron required more than 100% more energy than the fiberglass tub.

The cost for a standard vitreous china or fiberglass tub will range from \$80. to \$150. and galvanized from \$30. to \$50. Some fiberglass tubs are manufactured with attached shower stalls which will increase their cost. Water saving, functionally designed bathtubs need not cost more than conventional designs. However, due to the low demand for these fixtures, it is likely that the initial purchase price will be somewhat higher. When bathtubs larger than conventional sizes are considered, the cost goes up quickly. While the popularity of bathing for relaxation is growing, large bathtubs will cost in the range of \$500. or \$600. When a whirlpool spa is connected, the price jumps up to about \$1500. It is also likely that installation costs for large bathtubs will be higher due to their bulk and weight, and in some instances structural adjustments may have to be made to accommodate the increase floor loading when these bathtubs are filled with water. Once these units are installed then there is the increased operating cost for both water and hot water heating. For a whirlpool spa, the energy requirement for the electric pump would have to be considered. According to Milne (1976) large bathtubs and whirlpool spas will likely continue to be enjoyed by those who can afford them. It can only be hoped that a smaller tub is also installed into the dwelling or that a shower is used most often.

C.3 Shower Heads

Hot and cold water are mixed upstream of the shower head. This blend of water then flows through a common supply line to the shower head, through small openings, to produce a water spray. Most shower heads have a ball and socket joint which allows it to pivot and a few may have adjustable spray patterns, volume control or a shut-off valve built in. Some shower heads are connected to a short hose for hand-held use and many of these models have a clip to attach them to the wall so that when they are not being hand-held they can be used like stationary models.

C.3.1 Conventional Shower Heads. The shower is perhaps the most popular form of bathing because it provides a convenient, quick method of body cleansing and rinsing. The quantity of water used is highly variable and depends on the water pressure and the type of shower head which determines the flow rate and the duration of the shower which depends upon personal habits. Normal flow rates through conventional shower heads will vary from 15 to 40 L/min, depending on the particular model and the water pressure, with 25 L/min considered representative. Costs will vary from \$5. to \$25. with \$8. considered typical. More expensive massaging showering heads have flow rates as high as 55 L/min (Milne, 1976). However, regardless of the flow rate, the amount of water used will ultimately depend upon how long the individual spends in the shower, which is pretty much a matter of personal choice. Some individuals are in and out of their showers quickly, while others, particularly teenagers, may remain in the shower for 20 minutes or longer. Because of this, there is uncertainty within the literature as to an average shower duration. Although none are substantiated by actual measurements, most reports have assumed an average shower length of 5 minutes. Therefore, a typical shower with a conventional shower head would use 125 L of water.

C.3.2 Low Flow Shower Heads. Low flow shower heads are of two types. The standard head type looks like a conventional shower head with the water coming out of small holes. They usually have an adjustable spray from needle-sharp to rain-like. Many of these are essentially a conventional shower head with a flow restrictor added on and, therefore, the shower quality produced may be noticeably lower. The other type of low flow shower head are the aerating heads. They are smaller than conventional shower heads and do not have an adjustable spray. They mix air with the water spray to give the appearance of a much larger flow than is actually present.

A typical flow rate for both low flow types is approximately 9 L/min but will vary from 5 to 12 L/min, depending on the design and the water pressure. In recent tests by Consumer Reports (1978), 10 aerating and 18 standard low flow heads were evaluated, the latter with adjustable spray control. They found that, on the average, aerating heads were more economical with water using around 7.6 L/min at a moderate pressure of 350 kPa and about 9.5 L/min at a higher pressure of 550 kPa. Water consumption for most standard heads was about 9.8 L/min at moderate pressure and 11.4 L/min at the higher pressure. They also ran some tests at about 140 kPa, to see how well the low flow heads could handle low pressure conditions. Most of those tested could still deliver an acceptably strong stream of water, an important aspect when they are considered for use in buildings with individual internal water pressure systems. Consumer Reports (1978) also evaluated the low flow shower heads on the basis of spray pattern produced, the swiveling range of head and the shower quality. They noted that a shower is only as good as it feels and personal preferences will play an important part in shower head selection. Unfortunately, some of the low flow heads available produce a noticeably poorer quality shower. Many, however, produce an adequate and even superior shower compared to a conventional shower head, particularly those that have been completely redesigned for low flows. The average cost for a low flow shower head is about $10., slightly more than a conventional head, but costs will vary from $5. to $25. Installation onto existing plumbing takes only a few minutes.

C.3.3 Flow Controls. Simple devices that reduce the water used by an existing shower head are flow controls. These devices are basically a small diameter orifice which restricts the flow of water to the shower head. They are either a small insert designed to slip into the supply pipe or the shower head itself or a small fitting that threads between the shower arm and the shower head. The flow rate of a conventional shower will be reduced to about 10 L/min with a flow control installed, but depending on the particular device and water pressures, flows will range from 8 to 12 L/min. The major advantage of these devices is their low cost of $1. to $6. The Washington Suburban Sanitary Commission (1972) suggested installing a 1 cm sink washer in the shower head where it screws onto the water supply pipe for little or no cost. However, conventional shower heads are not specifically designed for a low flow and a restrictor may result in a less vigorous spray. When shower quality with a flow control is reduced to an unacceptable level, Consumer Reports (1978) suggests that a low flow shower head installation should then be considered.

C.3.4 Shut-off Valves. When showering, savings can be achieved if the spray is turned off while lathering up and using the shower only for wetting beforehand and rinsing afterwards. This type of saving can be accomplished through the use of a shut-off valve, installed between the shower arm and shower head. Having a shut-off at the shower head allows the water to be shut off and turned back on without having to readjust the hot and cold water feed controls to obtain a desirable temperature. Some shower heads will have this feature built in while others, particularly low flow aerating heads, will have it as standard or optional equipment. The disadvantages of shut-off valves are that the user may feel chilled when not under the shower spray and, therefore, would not use it. Also, water temperatures tend to change when the flow is shut completely off; however, this should not be experienced if a trickle flow of water is left, a feature incorporated into some shut-off valve designs. While savings with a shut-off will vary according to user habits, Consumer Reports (1978) considers them an advantage, since they do facilitate an additional water savings. Costs will vary from $2. to $5.

C.3.5 Thermostatic Mixing Valves. A plumbing device which increases user convenience, comfort and safety and promotes some water savings is the thermostatic mixing valve. This device has two control knobs, one permits the mixing of hot and cold water to attain a desired temperature level and the other controls the flow rate. The principle of operation is that once adjusted, the proportion of hot and cold water is varied automatically by means of an internal mechanism that is controlled by two metals which expand at different rates as the temperature or pressure of the incoming water is varied. Thus, the temperature selected is maintained and the bather is not in danger of being suddenly scalded or doused with cold water when other faucets are opened. This device reduces the amount of water wasted while the desired water temperature is being obtained from the hot and cold supply lines. It also enables the bather to turn off the shower when lathering up and to have the same temperature when the water is turned back on. This saves the water that would have been wasted as the water temperature was readjusted and the water that would have been wasted if the shower was left on in order to avoid the problem of adjusting the temperature again. Savings will vary according to user habits but could be as much as that claimed by the manufacturer, up to 40% of the warm water that would be used if conventional valves were used (Milne, 1976). The disadvantage of thermostatic mixing valves is that the $70. cost is two to three times that of conventional valves; however, they can be used to control multiple water fixtures. For example, they can control the water temperature for both the shower and bath or centrally located to control all the fixtures in the bathroom. Their most advantageous installation would be a public facility where they could be used to control water temperature and flow to multiple sinks and/or showers.

C.3.6 Pressure Balancing Mixing Valves. Similar to the thermostatic mixing valve, but specifically designed for shower use, is the pressure balancing mixing valve. It compensates instantly for pressure changes in either the hot or cold water supply lines, usually due to the use of other fixtures, thus, maintaining the selected flow mixture resulting in a consistent shower temperature. This is accomplished through a spool in a balancing cartridge which slides over to reduce the flow of water in the unaffected line. When pressure is restored, the spool returns to its original position. If there was a pressure increase in either water line, the spool would react the same only in reverse. However, they will not compensate for temperature fluctuations from the source unless accompanied by a corresponding pressure change. Pressure balancing mixing valves provide for essentially the same user convenience as the thermostatic mixing valve but at a lower cost of approximately $50; still more than conventional equipment.

C.4 Specialty Shower Systems

Within this category, three methods of bathing are discussed. These are the hand-held shower, air assisted shower system, and the atomizer shower.

C.4.1 Hand-held Showers. While hand-held showers are quite common, they are included as a specialty shower system because of their versatility as a complete system or their ability to compliment a stationary shower head or bathtub. Hand-held showers are attached to a flexible hose so they can be easily moved to allow the user to direct the water spray or to move it closer to get the full force of the spray. This in itself can reduce water use below that of stationary models. Hand-held showers can also be used to compliment conventional or low flow showers. They are particularly useful in the case of low flow showers where some users may feel that there is not sufficient spray or it takes too long to wet and rinse suds when washing hair.

Hand-held showers need not be permanently attached for use in a shower stall, they can also be connected to the end of a faucet for use in a sink or tub. With this capability, a shower stall is not always necessary and all that is required is a water supply and a means to collect and/or dispose of the wastewater that results. A disadvantage of these units is that they require the use of one hand when not clipped to the wall and used like a stationary model. Another disadvantage is the potential danger of contamination by back-syphonage, a condition which might occur if the shower head rests in a tub or basin filled with water. Flow rates usually range from 10 to 30 L/min except for the massage type which will be greater. A flow restrictor can be built-in or installed to reduce the flow rate. An on/off switch is incorporated into some models or one can be added. The normal price range is from $10. to $30., including the flexible hose and wall bracket.

To reduce water use, the hand-held shower can be used in a wetting and rinsing operation and turned off when lathering up. A unit designed to reduce water use was developed by the United States Naval Ship Research and Development Centre and evaluated by Schalzberg et al (1975). The nozzle in the unit restricts flow to 3 or 4 L/min and it incorporates a spring-loaded on-off device into the hand grip. Therefore, there is a water flow only when the handle is being squeezed. To control water temperature and further reduce water use a thermostatic mixing valve is required and a check valve is necessary in either of the supply lines to prevent water movement between them when the unit is off. Also, instant hot water should be available, therefore, the hot water should be circulated. With such a system, they found that showering required only 10 L of water and it was easier to install, less expensive and better received than an air assisted shower system (Kelly, 1978). When commercially available, this hand-held unit should cost approximately $25.

C.4.2 Air Assisted Shower Systems. A reduced flow bathing shower which provides satisfactory bathing while using approximately 90% less water than a conventional shower is the air assisted shower system. Although it looks like conventional equipment, it uses water at a rate of only 2 L/min. To achieve this, a small centrifugal air blower supplies air to a special shower head where the air and water are mixed to create a fine full stream effect. The air blower can be located above the ceiling or behind the wall. The air intake for the blower is located in the housing around the shower head, where the use of warm saturated air saves energy that would otherwise be required to warm up cold air. To contain the warm air and to prevent drifting of the spray, an enclosed shower stall is required. Hot and cold water is supplied by two 9.5 mm lines which run to a single handle shower valve where a single tube then runs on to the special shower head. Because of the low water flow rate it would take a long time to drain cooled water standing in the hot water line. The maximum distance to the hot water heater should be 15 meters. Alternatively, continuous hot water circulation or an in-line water heater could be used. The main disadvantage of this system is its capital cost of about $325 per complete unit. and the installation cost. Retrofitting this shower system will usually be difficult and expensive and sometimes impractical depending on the building. For each system installed, a separate air blower is required, therefore, there are no cost savings for a multiple installation. The power requirement of the 400 watt air blower is quite low. For example, a family of four who showers every second day would require 25 kW·h per year.

C.4.3 Atomizer Shower. The last of the specialty shower systems, discussed here, is the atomizer shower. Essentially this is a makeshift shower comprising of a container of warm water, of the desired temperature, which is delivered by either pressurizing the container or hand pumping to an atomizing nozzle that produces a very fine spray or mist. Cleansing of this nature was proposed by Buckminster Fuller who reasoned and later demonstrated that the feeding of atomized water and air under pressure onto the skin's surface would accelerate the surface oxidation, and release the surface cells themselves, along with the attached dirt (Ortega et al, 1972). The advantage of this sytem is that bathing uses extremely little water, as low as 1 litre per shower; however, the technology and plumbing are not fully developed for household installation. In addition, there may be drifting of the spray if not used within an enclosure and it takes a long time to have a "complete shower." An alternate system may be required for hair washing. However, this is truly a self-contained shower system, requiring extremely little water with no sewer or power hookups and it is portable. For the makeshift atomizer, shower costs will range from $5. to $30. depending on the type of equipment purchased.

C.5 Economic Analysis

Bathing is a highly variable personal experience and there is little data on typical frequency, water temperature, flow rates, duration and preferences for shower versus tub baths. It is difficult, if not impossible, to measure the quality of a shower obtained at a particular flow rate or to compare the spray patterns obtained with various models.

Other choices, such as shower versus tub baths, may provide the same end results but they can not easily be compared in terms of satisfaction. Still it is important to estimate the cost of various alternatives so that the user can select a method of bathing with full knowledge of the costs.

An economic analysis should be based on a particular number of uses per year. For example, a typical household of four on a piped system with conventional equipment would have approximately 630 baths per year. Because not all of these would be showering and the frequency is highly variable and unknown for houses on truck systems, it is also useful to know the number of uses per year at which a particular alternative becomes economical. For comparative results, it is assumed that the bathing water temperature is 40°C and, therefore, it is heated 35°C. An average of 5 minutes is used for showering duration. The same values are used for low flow shower heads since there is not any evidence to indicate that these are changed.

With these assumptions, the cost per bath for electrical heating of hot water is:

Cost/bath = Water Use/Bath (Cost of water + 0.041 x Cost of electricity). Utilizing this equation, the average costs per bath for the various bathing alternatives at four unit rate conditions are presented in Table C-1. The benefits in terms of water and energy use can thus easily be compared.

Over a 10 year period at a discount rate of 10%, the Present Value Factor (PVF) is 6.144 and the Present Value of each alternative with an installed cost of I and U uses per year is:

Present Value = I + (U x PVF x Cost/Bath)

From the earlier discussion and Table C-1, it can be seen that a normal tub bath of 150 L uses a little more water than a conventional shower of 125 L but far more than a low flow shower at 45 L per shower. Even if this were reduced by the use of smaller, insulated and better designed tubs and through user habits, it is unlikely this could be reduced below that of a low flow shower and, therefore, tub bathing is system is its capital cost of about $325 per complete unit. and the installation cost. Retrofitting this shower system will usually be difficult and expensive and sometimes impractical depending on the building. For each system installed, a separate air blower is required, therefore, there are no cost savings for a multiple installation. The power requirement of the 400 watt air blower is quite low. For example, a family of four who showers every second day would require 25 kW·h per year.

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TABLE C-1. AVERAGE COST PER BATH

	PIPED SYSTEMS		TRUCKED SYSTEMS	
	Condition 1	Condition 2	Condition 3	Condition 4
Unit Cost of Water	$0.10/1000 L	$1/1000 L	$10/1000 L	$20/1000 L
Unit Cost of Electricity	$0.05/kW·h	$0.20/kW·h	$0.05/kW·h	$0.20/kW·h
Alternatives	$	$	$	$
Tub Bath - 150 L				
Water	0.015	0.150	1.500	3.000
Heating	0.300	1.230	0.300	1.230
Total Cost	0.315	1.380	1.800	4.230
Conventional Shower - 125 L				
Water	0.013	0.125	1.250	2.500
Heating	0.256	1.025	0.256	1.025
Total Cost	0.269	1.150	1.506	3.525
Low Flow Shower - 45 L				
Water	0.005	0.045	0.450	0.900
Heating	0.092	0.369	0.092	0.369
Total Cost	0.097	0.414	0.542	1.269
Air Assisted Shower - 10 L				
Water	0.001	0.010	0.100	0.200
Heating	0.021	0.082	0.021	0.082
Total Cost	0.022	0.092	0.121	0.282
Hand-held Shower - 10 L				
Water	0.001	0.010	0.100	0.200
Heating	0.021	0.082	0.021	0.082
Total Cost	0.022	0.092	0.121	0.282

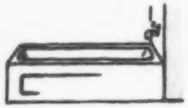
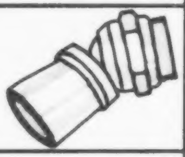
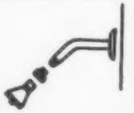
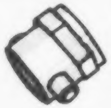
It can also be seen that for all practical conditions, it is economical to modify an existing shower head with a flow restrictor or to install a low flow shower head. For example, at the low piped rates of $0.10/1000 L and $0.05/kW·h the installation of a low flow shower head saves $0.17/use over an existing conventional shower head and if the installed cost is $18. it pays for itself after 105 uses or only 17 uses per year over a 10-year period. The present value of the savings at 500 uses per year would be $500. At higher electrical rates and for truck systems, the savings are even greater. For example, at the low truck rates of $10/1000 L and $0.05/kW·h, the savings are $0.96 per 5 minute shower. Therefore, retrofitting a low flow shower head becomes economical after only 20 uses and the present value of the savings at 250 uses per year is $1460. With such staggering savings it is obvious that all conventional shower heads should be immediately replaced with low flow shower heads. It is also obvious that the initial cost of the shower head is insignificant, therefore, the primary concern in choosing one is user satisfaction.

Also, for both the piped and trucked systems an inexpensive on/off control can quickly pay for itself and is usually worth obtaining. A hand-held shower compliments the low flow shower head and should be installed to make the system more attractive and to facilitate even lower water use. The same applies to the thermostatic and pressure balancing mixing valves which on their own may not be economical.

The air assisted shower system is considerably more expensive than the low flow shower head, particularly for the retrofit situation where it may often be impractical to install. This system must include a shower stall, thermostatic mixing valve and instant hot water. If this system could be installed for $700. it would be more economical than a low flow shower head providing the number of uses per year were greater than 230 and 100 at low truck rates of $10/1000 L and $0.05/kW·h and high truck rates of $20/1000 L and $0.20/kW·h, respectively. For most households this would be uneconomical or at least unattractive.

With a self-closing hand-held shower system bathing can be achieved with as little as 10 L per shower, which is the same as a 5 minute shower with an air assisted shower system. This system also requires a shower stall, thermostatic mixing valve and instant hot water. At 250 uses per year, the present valve of the benefits with such a system, compared to a low flow shower head, are $950. and $1600. at the low and high truck rates, respectively. The capital cost for this system will vary, but such a system is less expensive and easier to install than an air assisted shower system and is, therefore, more economically attractive. It can be used as a supplement for a low flow shower head or as the primary system where water is limited or very expensive. However, it will require a significant change in bathing style which will be unattractive to many people.

Table C-2 Bathing alternatives

	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Bathtubs 	Vitreous china, fiberglass, or metal bathtub is filled with mixture of hot and cold water for bathing.	Facilitates personal hygiene and relaxation. Can be used without plumbing system and water can be reused. Level to which tub is filled need not be excessive, and water use is independent of duration of bath. Water can be left in tub to recover heat before discharge.	Uses relatively fixed volume of water per use. Large bathtubs with or without whirlpool spas, use large volumes of water. Most are not designed to conform to the shape of human body or insulated to reduce heat loss.	Varies from none to 9.5 mm H&C water and 38 mm waste.	Varies with size of tub and user habits. Approx. 150 litres/use.	Galvanized $30-$50 Vitreous china & fiberglass $80-$250	Depends on cost of water and energy for hot water heating.
Conventional shower heads	Blend of hot and cold water flows through a fitting with small openings to produce a water spray.	Convenient, quick method of body cleansing and rinsing. Water use can be regulated by time spent in shower.	Requires water and sewer plumbing and shower stall. Water consumption is high particularly with "massaging" type showerheads. Flow restrictors installed on some models may reduce the quality of shower to unfavorable as may low pressure systems.	9.5 mm H&C water and 38 mm waste	15-40 Lpm Typically 25 Lpm "massaging" as high as 55 Lpm. Normal shower duration is 5 mins.	Normal $5-$25 Typically $8. massaging $20-$50	Depends on costs; 5 minute shower every second day for family of four would use about 250 litres per day; ½ hot water.
Low flow shower heads 	Same as above, except water flow is restricted. Aerating types mix air with the water.	Same as above, except uses less water and energy to heat hot water for the same amount of time spent showering without sacrificing shower quality. Aerating types use less water. Most work well on low pressure systems by delivering a constant water flow regardless of pressure changes.	Generally a little more expensive than conventional shower heads and spray pattern is often narrower. Low flow may be noticeable by some, particularly for washing hair. Aerating type have non-adjustable sprays.	Same as above.	5-12 Lpm Typically 9 Lpm	$5-$25 Typically $10.	Same as above, except family of four would use about 90 litres per day, ½ hot water.
Flow controls 	Small diameter orifice which restricts the flow of water. They are either an insert that slips into the shower water supply line or an independent fitting that is coupled onto the supply line ahead of the shower head.	Inexpensive retrofit method of reducing the flow of conventional shower heads. Can be homemade, consisting of a rubber washer with small diameter opening.	May reduce shower quality of some conventional showerheads.	Attaches, threads or inserts ahead of shower head.	8-12 Lpm Typically 10 Lpm	$1-$6.	Same as conventional, except consumption would be reduced to about 100 litres per day, ½ hot water.
Shut-off valves 	A valve installed between the shower arm and the shower head to allow turning off of the water at the shower head without adjusting other controls. Some shower heads have shut-off valve built in.	Saves water by allowing user to conveniently shut off water at the showerhead while not under spray, lathering up, washing hair, etc. Some types have a small water flow while in off position which maintains the selected water temperature.	Water temperatures in riser stem or supply lines may change while valve is turned off. User may feel chilled when shower spray is turned off.	Attaches ahead of shower head.	Varies with flow rate and user habits.	$2-$5	Depends on flow rate and user habits. Approx. 0 to 50% savings.
Thermostatic mixing valves	Controls temperature changes from the hot and cold water supply lines by means of sensitive bi-metal spring. Two metals expand at different rates causing spring to move interior mechanism which controls the hot and cold supply lines, thus, maintaining a constant ratio of hot and cold water. Has two control knobs; one for temperature selection and the other controls the rate of water flow.	Provides constant pre-selected water temperature regardless of flow (pressure) or temperature changes in hot or cold supply lines. Increases user convenience, comfort and safety by reacting quickly to supply line temperature changes. One valve can control both shower and bath and/or other outlets.	Costs two to three times the price of conventional valves.	9.3 mm H&C water and supply line to shower head.	Not applicable, reduces waste.	Approx. $70.	None
Pressure balancing mixing valves	Designed specifically for showers, it compensates instantly for pressure changes in either the hot or cold water supply lines, usually due to the use of other fixtures, thus, maintaining the selected flow mixture resulting in a consistent shower temperature.	Avoids discomfort and wasting of water by maintaining a consistent shower temperature.	Does not compensate for temperature changes from source unless accompanied by a pressure change. Costs about twice as much as conventional valves.	9.5 mm H&C water and supply line to showerhead.	Not applicable, reduces waste.	Approx. $50.	None

→

Table C-2 Bathing alternatives (continued)

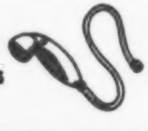
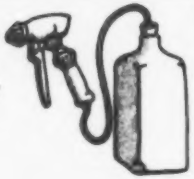
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Hand held showers 	Shower head type fitting attached to a short hose, for hand held use. Can be permanently attached for use in shower stall or connected to end of faucet on sink basin.	Increases ability to get the water spray where it is desired with a minimum of inconvenience. Available with built in flow control and on-off valve. Can be permanently clipped to wall or attached to any faucet. Can be used to compliment conventional or low flow shower head, particularly for washing hair.	Potential danger of contamination by back-syphonage. If not clipped to wall, requires use of one hand. The wetting and rinsing operation may be inconvenient to some.	Faucet or shower outlet and 38 mm waste.	4-38 Lpm greater for massage type.	$10-$30	Depends on costs and user habits. As low as 10 L/ shower.
Air assisted shower system	A small centrifugal air blower supplies air to a special showerhead where air and water are mixed to create a fine spray.	Very low water consumption while maintaining satisfactory cleansing. Can use in-line heater, therefore, no need for hot water supply line. Main economic advantage is amount of energy saved in water heating.	High capital and installation cost. Due to length of time required to drain water in hot water supply line, in-line heater, circulation of hot water or short distance to hot water tank is necessary. Requires enclosed shower stall. Separate blower required for each showerhead. Unsatisfactory shower for some.	9.5 mm H&C water 38 mm waste 120V electrical for blower.	2 Lpm	$325	Depends on costs, family of four would use about 20 litres per day, ½ hot water. 25 kW·h (400 watts) per year for compressor.
Atomizer shower 	Water of the desired temperature is delivered to an atomizing nozzle which produces a very fine spray (mist). The atomized water spray removes surface cells, dirt and soap.	Uses extremely little water. Existing designs are self-contained and require no water, sewer or power hookups and are portable.	Takes a long time to have a "complete shower." Drifting of spray if not within an enclosure. May require additional system for washing hair. Technology and plumbing not fully developed for conventional houses. Unsatisfactory shower for many.	None for self-contained models.	As low as 1 L/ shower	Approx. $5-$30	Negligible

Table C-3 Shower devices

Supplier	Flow control fittings (in-line)	Low flow shower heads	Flow cut-off valves	Thermostatic mixing valves	Specialty shower systems	Others
American Standard 80 Ward Street Toronto, Ontario M6H 4A7 Tel. (416) 534-3521	●	●				
Aqua-Aid of Canada Ltd. 17 Main Street North Newmarket, Ontario L3Y 3Z6 Tel. (416) 898-4441	●					
Bartle and Gibson Co. Ltd. 7214 Fort Road Edmonton, Alberta T5B 4E8 Tel. (403) 474-8991 Distributor of Kohler products		●		●		
Chatham Brass Co., Inc. 111 Park Lane Brisbane, California U.S.A. 94005 Tel. (415) 467-9100		●				
Crane Canada Limited 5800 Cote de Liesse Road Montreal, Quebec H4T 1B4 Tel. (514) 735-3592	●	●				
Eaton Corporation Controls Division 191 E. North Avenue Carol Stream, Illinois U.S.A. 60187 Tel. (312) 682-8000		●				
Eljer Plumbingware Wallace Murray Corporation Room 1230 Two Pennsylvania Plaza New York, New York 10001 Tel. (212) 244-8715		●				
Gerber Plumbing Fixutres Corp. 4656 West Touhy Avenue Chicago, Illinois U.S.A. 60646 Tel. (312) 675-6570		●				

Table C-3
(cont')

Supplier	Shower devices Flow control fittings (in-line)	Low flow shower heads	Flow cut-off valves	Thermostatic mixing valves	Specialty shower systems	Others
Laddie Lowen, Trans Atlantic Import Co. Ltd. 4806-51 Ave., P.O. Box 6023 Wetaskiwin, Alberta T9A 2E8 Tel. (403) 352-4204 Distributor of Beacon Valve products	●					
MacKay-Morton Limited 50 Myrtle Street Winnipeg, Manitoba R3E 2R2 Tel. (204) 786-5891 Distributor of Dole Flow products	●					
Merwin Manufacturing, Inc. Post Office Box 509 Dunkirk, New York U.S.A. 14048 Tel. (716) 366-4103		●				
Metro Watersavers P.O. Box 4306 South Edmonton, Alberta T6E 4T3 Tel. (403) 436-1720		●				
Minuse Systems, Inc. 206 North Main Street Suite 300-P.O. Box 905 Jackson, California U.S.A. 95642 Tel. (209) 223-0381					●	
Moen Faucet Division 377 Woodland Avenue Elyria, Ohio U.S.A. 44035 Tel. (216) 323-3341		●				
Noland Company National Accounts 2700 Warwick Blvd. Newport News, VA U.S.A. 23607 Tel. (804) 244-8441	●					

Table C-3
(cont')

Supplier	Shower devices: Flow control fittings (in-line)	Low flow shower heads	Flow cut-off valves	Thermostatic mixing valves	Specialty shower systems	Others
Ny-del Corporation 740 E. Alosta Avenue Glendora, California U.S.A. 91740 Tel. (213) 335-2213	●	●				
Savway Dual Flush Co. 930 Clarkson Avenue Brooklyn, New York U.S.A. 11203		●				
Sexauer, J.A. Inc. 10 Hamilton Avenue White Plains, New York U.S.A. 10601 Tel. (914) 682-8600	●	●				
Speakman Company P.O. Box 191 Wilmington, Delaware U.S.A. 19899 Tel. (302) 764-7100		●	●	●		
Walker Crosweller & Co. (Canada) Ltd. P.O. Box 148 Markham, Ontario L3P 3J5 Tel. (416) 297-2173		●		●		
Watersavers, Inc. P.O. Box 22326 Cleveland, Ohio U.S.A. 44122 Tel. (216) 292-2550	●					
Waterwise Products P.O. Box 2781 Yellowknife, N.W.T. X0E 1H0 Tel. (403) 873-5271		●				
Water Wizard, Inc. P.O. Box 184 Croydon, Pennsylvania U.S.A. 19020 Tel. (215) 946-5702		●				

Table C-3 (cont')

Supplier	Shower devices					
	Flow control fittings (in-line)	Low flow shower heads	Flow cut-off valves	Thermostatic mixing valves	Specialty shower systems	Others
Whedon Products, Inc. Box U, Station A 2074 Park Street Hartford, Conn. U.S.A. 06106 Tel. (203) 232-9877		●				
Zin-Plas Corporation 1007 North Division P.O. Box Q Grand Rapids, Michigan U.S.A. 49501 Tel. (616) 454-9441	●	●	●			

APPENDIX D

LAUNDRY ALTERNATIVES

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D. LAUNDRY ALTERNATIVES

In recent years the amount of household water normally used for the laundry has increased relative to total usage (Siegrist et al, 1976). This has been primarily due to the introduction of the automatic washer and concurrent changes in the habits of the user. Presently, the average household uses approximately 14.6% of their total water requirement for laundering purposes. The reported values in Table 2 range from 4% to 27%, which indicates a large variation in household laundry water usage. However, assuming that the average value is indicative of an automatic washer requiring 190 L of water per full cycle, a household of four on a piped system which would normally use 900 L of water per day would wash 251 laundry loads per year, or about 5 loads per week. For houses on a fully trucked system, if the percentage of household water distribution remains the same, the family of four would do approximately 106 wash loads per year. These values are used as a common base for the economic analysis in Section D.5 of this Appendix. The various laundry alternatives are discussed below and a summary is presented at the end of this Appendix in Table D-6, followed by a list of suppliers in Table D-7.

D.1 Hand Laundry

Although hand laundering is still a common practice in various parts of the world, for most of us it is almost a thing of the past. Normally, hand laundering is used as a supplement to a laundry machine for delicate items or is used in emergency situations. Advantages are that it does not require household plumbing and water use is low and controllable. The major disadvantage is that hand laundering is very labour intensive, discouraging frequent use. For this reason, it is not considered here as a household laundry alternative.

D.2 Wringer Washers

The rugged old style wringer washers are still in limited use, primarily in rural areas including many northern communities. With this type of washer the user has complete control over the filling and draining of water and the operating duration. The tub can be filled either by hand or from a faucet and used washwater is drained to a convenient sewer outlet. The user controls the operating time by manipulating a gear for start-stop agitator motion. Laundered articles are manually fed through a wringer to remove excess water which then drains back into the tub. Wringer washers are normally powered by an electric motor but some have been converted to a small adequately vented gasoline engine, which makes them useful where electricity is not available. The advantage of a wringer washer is that a number of wash loads can be done in the same wash and rinse water, usually starting with the lightest coloured, less soiled articles. Water use is therefore controllable, but unless "reuse" is practiced water use would be comparable to the more convenient automatic washers. Due to its dependence on user habits, it is difficult to estimate water savings and it is excluded from the economic evaluation of laundry alternatives. While the use of a wringer washer will probably result in water savings, their selection is left up to individual preferences.

D.3 Conventional Top Loading Automatic Washers

While the convenience and labour saving value of the automatic washer has been tremendous, several studies have expressed concern over the limited amount of savings that can be obtained through presently available conventional models. Howe and Vaughan (1972) concluded that unless entirely unforeseen technologies came along or water prices escalated tremendously, it would not be reasonable to expect much of a reduction in household washing machine water use. They also suggested that with some prodding, manufacturers might pay more attention to the water and energy requirements of their designs. The literature is clear in stating the need for research and development in this area, however, a few authors have shown that savings in both water and energy are possible through the careful selection of an automatic washer and through efforts of the consumer to use them more efficiently.

Among currently available automatic washers, there exists a rather large range of water use per cycle. Tests conducted by Consumer Reports, (1975) on some of the leading American washers, indicated a range of water usage varying from a low of 140 L/cycle to a high of 261 L/cycle. Tests were conducted with a 3.6 kg load and 275 kPa water pressure with a maximum water fill on two wash/rinse cycle settings of regular and permanent press. The results also indicate that some washers use more water for a permanent press wash. Results of these tests are presented in Table D-1 in increasing order of water use. The average regular cycle wash uses 183 L of water but the range varies from 140 to 200 L.

When purchasing a top load washer, it would be advisable to ask about the amount of water and electricity required to complete a normal cycle. The selection of a lower water using automatic washer results in savings in water and the energy required for hot water heating, as well as providing reductions in laundry additives such as detergents and bleach. The load capacities of the washer is also important since this influences the number of laundry loads and the efficiency of operation. For example, white, colored, and special materials all have to be laundered separately, and for an individual or small family, this often means doing a load of washing for a few articles in the same amount of water that could be used for a larger load. Thus, a smaller capacity machine would waste less water. On the other hand, Consumer Reports (1975) have observed that a large or medium size family may save water by using a higher capacity machine and doing full wash loads. Generally, the higher water use machines are rated for a 6.4 to 8.2 kg wash load, and the low water use machines for a 5.4 to 6.4 kg wash load.

A survey revealed that the average laundry load is only 3.2 to 4.1 kg in a majority of U.S. households, well within the rated capacities of most automatic washers (Chevalier, 1978). Consumer education on the water requirements and the use of automatic washers would be advantageous for most households. The AWWA Committee Report (1973) on Water Use reported that where central laundry facilities are used, inconvenience and usually a charge per load promote more full-load operations and, therefore, more efficient water use than might generally be experienced in the single family home. Because of available facilities and no direct payment for each wash load, the single-family household may not

TABLE D-1. WASHING MACHINE WATER USAGE(1)

	Regular Cycle(2) Water Used (Hot Wash/Cold Rinse)		Permanent Press Cycle Water Used (Warm Wash/Cold Rinse)	
	Hot(3)	Total	Hot(3)	Total
Normal Water Use	litres	litres	litres	litres
Top Loading				
Maytag A2075	60.6 (102.2)	140.1	30.3	185.5
Speed Queen DA3690	71.9	143.8	22.7 (64.4)	147.6
Maytag A606	68.1	155.2	34.1	196.8
General Electric WWA7030P	83.3 (128.7)	170.3	41.6	170.3
Hotpoint WLW3600P	90.8	177.9	41.6	196.8
Hamilton WA384	83.3	177.9	41.6 (98.4)	200.6
Gibson WA83312A	90.8	181.7	45.4	204.4
Admiral LWA1835	90.8	181.7	30.3	193.1
Frigidaire WCD	87.1	185.5	41.6	238.5
Wards Signature 6224	87.1	189.3	37.9	189.3
Penneys	90.8 (121.1)	189.3	30.3	189.3
General Electric WWA8310P	90.8 (128.7)	193.1	34.1	177.9
Sears Kenmore 24501	94.6	193.1	53.0	208.2
Whirlpool LAA5800	94.6	193.1	53.0	261.2
Wards 6424	90.8	196.8	45.4	196.8
Norge LWA 2070	90.8	196.8	45.4	196.8
Wizard 5WC2340	90.8	196.8	45.4	196.8
Kelvinator W624G	94.6	196.8	34.1	212.0
Hamilton WA373	94.6	196.8	34.1	212.0
Westinghouse LA495P	87.1	200.6	49.2	200.6
Average	86.7	182.8	39.6	198.7
Low Water Use				
Front Loading				
Westinghouse WLT170	39.7	119.2	19.8	119.2
Top Loading				
Speed Queen AD151	53.0	132.5	26.5	145.7

---

(1) Data from U.S. Consumer Reports (1975) with the exception of the Low Water Use machines which are based on manufacturers literature.

(2) Water Pressure at 275 kPa, 3.6 kg load, and maximum water fill.

(3) Where the hot wash/cold rinse or warm wash/cold rinse combination is available only by resetting temperature control after wash fill, the litres used if not reset are shown in parentheses.

1 L = .220 I gal; 1 kPa = .145 psi; 1 Kg = 2.205 lb.

strive for full-load capacity with each operation of the washer. It is apparent that not only is there a need for consumer education on water use but also the need for consumer incentive. This need is more apparent within the laundry area since large reductions in usage are required to effect any significant change in the total household water demand.

D.3.1 Suds Saving Device. Some automatic washers offer a suds saving device which will permit re-use of the warm water from the first load for the next load. Milne (1977) estimated laundry water savings with a suds-saver device as 20% if the wash water was reused once, and 26% if the wash water was reused twice. However, consumer acceptance of the suds-saver has been poor and some feel that washers equipped with this device do not seem to perform as well as other machines (Chan, et al, 1976; Milne, 1977; Muller, 1975). The higher cost of this option and the additional separate water storage facilities required could also deter acceptance and application.

D.3.2 Convenience Features. Savings may also be achieved through two basic convenience features common to most modern automatic washers. Firstly, the washer should be equipped with a water level setting control which will permit partial filling of the tub if less than a full load is to be washed. Average savings have been estimated as high as 45 L/cycle (25%) by the Washington Suburban Sanitary Commission (1972), but this depends upon habits of the user and type of washer. When this feature is not available, the user could postpone laundering until a full load has been accumulated. Secondly, the automatic controls should allow cold water rinsing regardless of the temperature selected for the wash part of cycle. Hot or even warm water rinsing has generally been regarded as unnecessary and its wastes energy required for hot water heating.

Muller (1975) suggested and presented an excellent argument for extending the energy savings realized through cold water rinsing to include the wash part of cycle. The potential energy savings are considerable, but several questions remain as to the possible hazards to health from the greater number of surviving bacteria from a cold (or warm) water wash without a disinfectant additive. Giving arguments both for and against, Muller invited comments by Public Health authorities on his conclusion that cold (or warm) water laundering without a bacteriacide is appropriate and poses no serious threat to health where (a) all members of the family enjoy reasonably good health, and (b) where the clothes, after laundering, will be dried in a dryer or outdoors on the line.

D.4 Low Water Use Automatic Washers

Also given in Table D-1 under Low Water Use is data on two washers presently available in Canada, the White-Westinghouse front-load model WLT-170 and the Speed Queen top load model AP151. These two washers offer the greatest potential for savings through lower water use, and both have the water level and temperature selection convenience features discussed earlier. Their approximate initial capital costs are $700. and $625., respectively, which is higher than the average of the conventional top load washer of $550. Information on these two washers was collected from manufacturers advertising literature.

These two low water use machines should not be considered as the only water conserving alternatives available. For example, a Maytag model A608 and a Speed Queen model FA6010 had comparable consumption values and had the lowest water use of the fourteen conventional top loaders recently tested by Consumer Reports (1978). Unfortunately, a front load washer was not included in these tests. Other conventional automatic top loaders also have relatively low water requirements, and their rated load capacities may be better suited to a particular family. The White-Westinghouse and Speed Queen low water use models are respectively rated for a 6.4 kg and 5.4 kg wash load, while the higher water use machines are rated for 6.4 to 8.2 kg loads. However, given the same conditions these low water use machines do offer substantial savings in terms of water use and energy required for water heating.

D.4.1 Front Loading. Front load automatic laundry machines utilize a tumble action, much like hand washing, to sweep clothes through sudsy water and then lift, tumble and plunge them back into the water. This action provides cleaning with less water and energy than the agitator action of top loading machines. The design uses a belt drive rather than a transmission and the manufacturer claims that this reduces maintenance costs.

Front loading washers were referred to by Baker and Baily (1976) as apparently the only water saving laundry machines available. In their analysis, they assumed that the front loading automatic used 60% of the water used by a conventional top loader. A savings of 40% was also claimed in the amount of energy required to heat the laundry water. Conventional laundering was assumed to average 130 L/person·d for a family of four. Similarily, independent tests by the manufacturer of the front loading washer claimed savings of 36% in total water, and 41% in hot water use (White-Westinghouse, 1976). The more efficient tumble action of the front loading washer was also reported as having an operating electrical requirement of 0.18 kW·h per full cycle. Compared to four leading top loading washers tested with a range of 0.19 to 0.34 kW·h this represented an average savings of 0.05 kW·h per medium size load. The manufacturer also points out that front loading washers will get clothes equally clean with half the detergent and other laundry aids required by the top loading washers, a savings of about $0.10 per load. Total savings in water, energy and laundry additives were calculated at about 40% of that required by the average of the top loaders. Apart from these savings, another interesting feature of the front loading automatic washer discussed here, is the manufacturers exclusive "weigh-to-save" loading door. By placing laundry to be washed on the loading door, a built in scale indicates the weight of the wash. Thus, the water level selection control can then be set for the optimum water use. This feature eliminates the guess work of selecting a proper water level for less than a full wash and may also serve as a reminder to the user of the various water level settings available.

Front load laundry machines have generally met with poor consumer acceptance, perhaps due to the location of the loading door; leakage from the door in earlier models; the fact that they are different; and poor marketing and availability (Chan, et al, 1976; Milne, 1977). They also cost more than comparable top loaders, even though they are simpler and should be less expensive to manufacture. This is primarily due to lower demand and volume of production. Front load laundry machines are much more common in households in Europe, while in North America they are primarily found in commercial laundromats.

D.4.2 Top Loading. As mentioned previously, there is also a low water use top loading automatic washer manufactured by Speed Queen. The major difference between this model's design and the others is that the laundry water is filled into a solid stainless steel inner drum rather than having a perforated inner drum within a larger outer drum. Water use for a regular cycle is 20% less than the average top loader and 10% greater than the front load model. It also has both the water level and temperature selection controls.

D.5 Economic Analysis

A general economic comparison between automatic washing machines is difficult due to different user requirements and habits combined with varying water, sewer and energy costs. In order to illustrate the procedure and typical results some assumptions are necessary before an analysis can be carried out. The assumptions used are:

(a) Temperature selection for the two wash/rinse cycle settings will be the same as those established by the Consumer Reports (1975) tests, with average hot water usage as that determined in Table D-2.

(b) Half of the laundry will be washed on a regular wash/rinse cycle and the rest on a permanent press wash/rinse cycle.

(c) A 3.6 kg load and maximum fill will be assumed for both cycle settings. As mentioned previously, the rated wash load capacities vary with some washers, and the White-Westinghouse front load washer and Speed Queen top load washer are respectively rated for a 6.4 kg and 5.4 kg wash load. The 3.6 kg load is well within the rated capacities of these two washers as it is with most others, and is representative of the U.S. survey indicating that a majority of wash loads are normally 3.2 kg to 4.1 kg.

(d) Cold and hot water temperatures are assumed to be 5°C and 55°C respectively, therefore, the hot water used must be heated by 50°C. Electric hot water heating is used and no account is made for any inefficiencies in heat transfer or in heat losses from the hot water heating system.

With these assumptions, the average water, energy and additive requirements per wash load for an average conventional top load and the low use top and front load washers are presented in Table D-3. The average cost per wash load were calculated from:

Total Costs per = (Total Water Use X Unit Cost of Water) + Hot Water Use X (Hot-Cold Water Temperature) X Energy Conversion Factor X Unit Cost of Energy + (Operating Electric Requirements X Unit Cost of Electricity) + (Amount of Additives Used X Unit Cost of Additives

TABLE D-2. AVERAGE HOT WATER USAGE(1)

	Regular Cycle %	Permanent Press Cycle %	Average Litres	Average %
Average of Top Load Washers	47.4	19.9	63.2	33.7
White-Westinghouse Front Load	33.3	16.6	29.8	25.0
Speed-Queen Top Load	40.0	18.2	39.8	29.1

(1) Using hot wash/cold rinse for regular cycle and warm wash/cold rinse for permanent press cycle.

TABLE D-3. AVERAGE USAGE AND SAVINGS PER WASH LOAD(1)

Consumption	Average Top Load Washers	Low Use(3) Top Load	Low Use(2) Front Load	Savings Per Wash Load: Low Use Top Load		Savings Per Wash Load: Low Use Front Load	
Water	190.8 L	139.1 L	119.2 L	51.7 L	27%	71.6 L	38%
Hot Water Only	63.2 L	39.8 L	29.8 L	23.4 L	37%	33.4 L	53%
Hot Water Heating	3.67 kW·h	2.31 kW·h	1.73 kW·h	1.36 kW·h	37%	1.94 kW.h	53%
Electricity (to operate washer)	0.23 kW·h	0.23 kW·h(4)	0.18 kW.h	-	-	0.05 kW·h	22%
Detergent	300 mL	300 mL(4)	150 mL	-	-	150 mL	50%
Bleach	225 mL	225 mL(4)	113 mL	-	-	113 mL	50%

(1) Based on the average consumption values of the regular and permanent press wash/rinse cycle setting.

(2) As reported by White-Westinghouse.

(3) As reported by Speed-Queen.

(4) Assumed.

For electric hot water heating, the Energy Conversion Factor is 1.16 X 10^{-3} kW·h/L·°C and with this value plus the requirements in Table D-3, the average cost per wash load is calculated and presented in Table D-4. Calculations were performed at four different water and energy costs which are typical of piped systems (Condition 1 and 2) and trucked systems (Condition 3 and 4). It can be seen that for piped systems the energy savings are dominant whereas for trucked systems the water savings are relatively more significant. The laundry additives savings could be higher than the $0.10 per load calculated where transportation costs increase the cost of detergent and bleach. In each case, the cost of the front load washer is 50% to 60% of that for the average of the conventional top load machines.

TABLE D-4. AVERAGE COSTS PER WASH LOAD

	PIPED SYSTEMS		TRUCKED SYSTEMS	
	Condition 1	Condition 2	Conditon 3	Condition 4
Cost of Water	$0.10/1000 L	$1/1000 L	$10/1000 L	$20/1000 L
Cost of Electricity	$0.05 kW·h	$0.20/kW·h	$0.05/kW·h	$0.20/kW·h
Alternatives	$	$	$	$
Conventional Top Load				
Additives	0.20	0.20	0.20	0.20
Water Cost	0.02	0.19	1.91	3.82
Energy Cost (1)	0.20	0.78	0.20	0.78
Total Cost	0.42	1.17	2.31	4.80
Low Use Top Load				
Additives	0.20	0.20	0.20	0.20
Water Cost	0.01	0.14	1.39	2.78
Energy Cost (1)	0.13	0.51	0.13	0.51
Total Cost	0.34	0.85	1.72	3.49
Savings over conventional	0.08	0.32	0.59	1.31
Low Used Front Load				
Additives	0.10	0.10	0.10	0.10
Water Cost	0.01	0.12	1.19	2.38
Energy Cost (1)	0.10	0.38	0.10	0.38
Total Cost	0.21	0.60	1.39	2.86
Savings over conventional	0.21	0.57	0.92	1.94

(1) For electric hot water heating and operation.

From the cost per wash load, the annual costs can be calculated knowing the number of uses per year. Since the lower water use washers have higher capital costs but lower operating costs, they become more economically attractive when they are used more frequently.

The initial and operating costs and an economic analysis of automatic laundry machine alternatives for the retrofit and new installation situations is presented in Table D-5. Using the same assumptions previously outlined, equations for the present value of each alternative in terms of the water and electricity rates and the number of uses per year are presented. To illustrate the economics for retrofit and new installations, the present values for each alternative for two piped and two trucked water and electricity rates and for 251 and 106 wash loads per year, or 4.8 and 2 wash loads per week, are presented. These usages are based on the number of washing loads per year expected for a piped and trucked household of four respectively if 14.6% of the total water usage was for washing in a conventional top load machine. Each household or situation will be different but these values cover a typical range. For any specific values of water and electricity rates, the present value increases linearly, therefore, the results presented can easily be interpreted for other usages using the present value equations or by plotting the results.

D.5.1 Piped Systems. From Table D-5 it can be seen that for the retrofit situation it is only economical to replace an existing conventional washer with a front load washer when usage as well as water and electricity rates are very high. For example, at the rates of \$0.10/1000 L and \$0.05/kW·h the break even point is at 610 uses per year and at the higher rates of \$1/1000 L and \$0.20/kW·h the break even point is at only 270 uses per year. Because of the higher cost and small savings, households on piped systems generally should not immediately retrofit a functioning conventional washer with a front load unit. Machines which receive high usage, such as an apartment building, would probably benefit from immediate retrofit.

For new installations, it can be seen that the higher priced front load washer is usually more economical than either the conventional

TABLE D-5 INITIAL AND OPERATING COSTS

ALTERNATIVE Code	Description	INITIAL COSTS Capital ($)	Installed (I) Retrofit(1) ($)	New(2) ($)	Total Water (L/Use)	OPERATING REQUIREMENTS Others(3)		PRESENT VALUE EQUATIONS (3,4)
1	Conventional Top Load	550	0(1)	700	190.8	Hot Water(5) Heating(6) Electricity(7) Detergent Bleach	= 63.2 L = 3.67 kW·h = 0.23 kW·h = 300 mL = 225 mL	$I + PVF(0.19R_W + 3.90R_E + 0.20)U$
2	Low Use Top Load	625	700	775	139.1	Hot Water Heating Electricity Detergent Bleach	= 39.8 L = 2.31 kW·h = 0.23 kW·h = 300 mL = 225 mL	$I + PVF(0.14R_W + 2.54R_E + 0.20)U$
3	Low Use Front Load	700	775	850	119.2	Hot Water Heating Electricity Detergent Bleach	= 29.8 L = 1.73 kW·h = 0.18 kW·h = 150 mL = 113 mL	$I + PVF(0.12R_W + 1.91R_E + 0.10)U$

PRESENT VALUE AND RANKING OF ALTERNATIVES (3,4)

	R_W = R_E = Rank	Piped Systems $0.10/1000 L $0.05/kW·h Alt.	PV($)	Piped Systems $1/1000 L $0.20/kW·h Alt.	PV($)	Trucked Systems $10/1000 L $0.05/kW·h Alt.	PV($)	Trucked Systems $20/1000 L $0.20/kW·h Alt.	PV($)
RETROFIT INSTALATIONS									
U = 251 (8)	1st	1	640	3	1700	3	2915	3	5195
	2nd	3	1095	1	1805	2	3350	2	6080
	3rd	2	1225	2	2005	1	3550	1	7395
U = 106 (9)	1st	1	270	1	765	1	1500	3	2640
	2nd	3	910	3	1165	3	1680	2	2975
	3rd	2	920	2	1250	2	1820	1	3125
NEW INSTALATIONS									
U = 251	1st	3	1170	3	1775	3	2990	3	5270
	2nd	2	1300	2	2080	2	3425	2	6155
	3rd	1	1340	1	2505	1	4250	1	8095
U = 106	1st	1	970	3	1240	3	1755	3	2715
	2nd	3	985	2	1325	2	1895	2	3050
	3rd	2	995	1	1465	1	2200	1	3825

NOTES:

(1) Assume that a Conventional Top Load washer is presently installed therefore it must be removed, where necessary, and it has no salvage value

(2) Includes all power and plumbing hookups

(3) Does not include Maintenance costs which are assumed equal for all washers.

(4) Assume a discount rate of 10% and an economic life of 10 years, therefore the Present Value Factor is 6.144

(5) Assume hot water heating by electricity.

(7) To operate washer

(8) If a typical household of 4 on a piped system uses 225 L/person·d x 4 = 900 L/d and 14.6% of that is for laundry, then a typical household would do approximately 251 wash loads per year.

(9) If a typical household of 4 on a fully trucked system uses 95 L/person·d x 4 = 380 L/d and 14.6% of that is for laundry, then a typical household would do approximately 106 wash loads per year.

WHERE:

I = Installed initial cost (Retrofit or New)

R_W = Rate for water and sewer service ($/1000 L)

R_E = Rate for electricity

U = Number of uses per year

PVF = Present Value Factor

PV = Present Value

Alt. = Alternative

or low use top load washer. At the lower rates of \$0.1/1000 L and \$0.05/kW·h, the break even point is at 120 uses per year and at the higher rates of \$1/1000 L and \$0.20/kW·h the break even point is only 50 uses per year. Therefore, for most households on piped systems there are potential savings to be had by installing a front load washer in new buildings or when an existing machine is to be replaced. For example, at 251 uses per year and the lower rates, the present value of the savings would be \$170 or \$30/a and at the higher rates the present value of the savings would be \$730 or \$120/a. For low rates and usage the costs are relatively close and the choice is not economically significant.

D.5.2 Trucked Systems. From Table D-5 it can be seen that for the retrofit situation it is economical to replace an existing conventional washer with a front load machine for most households. For example, at the rates of \$10/1000 L and \$0.05/kW·h the break even point is at 140 uses per year and at the higher rates of \$20/1000 L and \$0.20/kW·h, the break point is at only 65 uses per year. Therefore, apartment buildings or large households could substantially benefit from the retrofit, but small families or couples would obtain only marginal savings from a retrofit unless the existing machine had some salvage value.

For new installations it is practically always more economical to install a front load washer. At the lower truck system rates of \$10/1000 L and \$0.05/kW·h the break even point is at only 25 uses per year and at the higher rates of \$20/1000 L and \$0.20/kW·h the break even point is only 15 uses per year. There are substantial savings to be realized if a front load washer were installed instead of a conventional top load. For example, at the lower rates and only 106 uses per year, the present value of the savings is \$445. or \$70./year and at 251 uses per year, the savings are \$1260 or \$205/year. At higher usage and/or rates the savings are even greater. Therefore, front load washers are by far the most economical alternative for all new installations or when an existing washer is to be replaced. Because of the large savings over a conventional top load washer, it would be difficult to justify their continued used.

Table D-6 Laundry alternatives

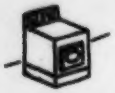
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Hand laundering	Beating or rubbing of articles together or rubbing on scrub-board in water filled tub or basin. Manual wringing of articles to remove excess water.	Complete user control over water quantity and temperature and number of articles laundered in same wash or rinse water. Does not require electrical hook-up or household plumbing.	Highly labor intensive requiring considerable time, inconvenience and effort. Water use depends on size of tub and user habits.	None	Depends upon user.	Low to none.	None
Wringer washer	Agitator washing motion in user filled tub. User activates pump to drain wash or rinse water from tub. Laundered articles are manually fed through wringer to remove excess water.	User control over water quantity and temperature and number of wash loads laundered in same wash or rinse water. Can be moved to convenient storage location.	Capacity of tub varies with manufacturer. Requires time but not nearly as inconvenient or labor intensive as hand laundering. Possible to overfill or use too much water for varying wash load sizes. Wringer can be hazardous. Requires electrical hookup and storage space.	120V electrical and should be close to water supply and sewer drain.	Varies according to size of tub, manufacturers recommendations and number of reuses of wash and rinse water. Usually less than automatic washers.	$200 - $500	Depends on cost of water and power. Household of 4 would wash an average of 5 loads per week.
Top loading automatic washer	Top loading agitator motion for preselected wash/rinse/spin cycles. Wash and rinse water is automatically filled and drained with excess water spun from laundered articles.	Convenient automatic wash and spin dry cycles are labor saving. Other convenience features allow for water level and temperature selection Some models offer a suds-saver attachment which will save water.	High range of water use among currently available models. Water level selection not possible on some models. Minimum wash load size may be high for small families. Temperature selection does not allow cold water rinsing on some models. Requires electrical and plumbing hookup and permanent space.	120V electrical and must be connected to water supply and sewer drain.	Total water use 140 - 260 litres Hot water only 40 - 87 litres	$350 - $700 average $500	Same as above
Low water use top loading automatic washer	Same as above.	Same as above except uses less water per cycle, promoting less use of detergents and other laundry additives.	Has slightly higher cost than average of other top load models. Maximum wash load sizes may be low for some families. Requires electrical and plumbing hookup and permanent space.	Same as above.	Total water use 133 - 146 litres Hot water only 27 - 53 litres	$575	Requires less water and laundry additives than above.
Front loading automatic washer 	Front-loading tumble wash motion for preselected wash/rinse/spin cycles. Wash and rinse water is automatically filled and drained with excess water spun from laundered articles.	Lowest water use of currently available automatic washers. Has water level and temperature selection convenience features. Uses less detergent and other laundry additives and requires less operational energy than average of top load models.	Front loading door is not preferred by many consumers. Has slightly higher cost than average of top loading models. Maximum wash load size may be low for large families. Requires electrical and plumbing hookup and permanent space.	Same as above.	Total water use 119 litres. Hot water only 20 - 40 litres.	$650	Requires less water, operating power and laundry additives than above.

Table D-7

Supplier	Washing machines Wringer washer	Front load automatic	Top load automatic	Others
Associated Commercial Appliances Ltd. 11640-147 Street Edmonton, Alberta T5M 1W2 Tel. (403) 454-7181 Commerical and coin-op Speed Queen Laundry Equipment			●	
Canadian Admiral Corp. Ltd. 501 Lakeshore Road Mississauga, Ontario L5M 4M5 Tel. (416) 278-5561			●	
G.S.W. P.O. Box 450 Weston, Ontario M5N 1E7 Tel. (416) 241-2611	●		●	
Inglis Limited 14 Strachan Avenue Toronto, Ontario M6K 1W6 Tel. (416) 366-7451 Also mfg. Sears Kenmore			●	
Maytag Company Ltd. 270 Bellfield Road Rexdale, Ontario M9W 1H5 Tel. (416) 675-3977	●		●	
McGraw-Edison of Canada Ltd. 225 Pinebush Road Cambridge, Ontario N3C 2W2 Tel. (519) 623-6500 Speed Queen Washers			●	
White-Westinghouse Executive Offices 503 Imperial Road P.O. Box 1060 Guelph, Ontario N1H 6N1 Tel. (519) 836-6340		●	●	

APPENDIX E

KITCHEN ALTERNATIVES

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E. KITCHEN ALTERNATIVES

The proportion of total household water consumption attributed to kitchen usage ranges from an estimated 9.0% to 16.0% with an average of 11.8% (Table 2). Assuming the percentage remains contant, this amounts to 38,763 L and 16,367 L per year for the piped and trucked systems, respectively. Approximately 66% of this usage (7.8% of the total) is used for dishwashing and food waste disposal and the remaining 34% (4% of the total) is used for drinking and cooking.

In today's modern home, it is not uncommon to find an automatic dishwasher and in-sink food waste disposal unit. Although the household water consumption of these two convenience appliances is but a small percentage of total use, several studies have examined the water requirements of each.

E.1 Dishwashing

The amount of water used for dishwashing depends on whether dishes are washed by hand or machine and on the individual's personal washing style. Milne (1977) estimated that hand washing the equivalent of a full dishwasher load of dishes, in a filled sink bowl and rinsing under a free flowing stream of water, would require 57 L of water. If instead the washing technique was to wash and rinse the dishes under a free flowing stream of water, the consumption might reach 97 L. Hand washing with a consideration to reducing water use could be done with much less water than this but may entail some inconvenience and possibly a lower quality of washing.

Automatic dishwashers utilize a spray of hot water to clean the dishes placed within them. A heating element in the dishwasher maintains the water at a high temperature and a pump is used to both circulate the water and to eject it after the wash and rinse cycles. Depending on the model, the dishes are dryed after cleaning by either radiant heat or circulated hot air.

Automatic dishwashers have a definite reservoir capacity, fixed valve arrangement and repetitive wash/rinse/dry cycle, therefore, approximately the same quantity of water is used for each full cycle of operation. A recent survey of the automatic dishwashers, by the Washington Suburban Sanitary Commission (WSSC, 1976), found that among the currently available models water use varied from a low of 45 litres to a high of 70 litres per full cycle. Among those tested were also several models which featured a cycle adjustment control with which consumption could be reduced to as low as 26.5 litres per cycle. Results of this study appear in Table E-1. However, it should be noted that if the dishes are rinsed at the sink under free flowing water before placing them in the dishwasher, the water consumption will be greater; and that pots and pans are often pre-washed by hand, also increasing water consumption. A dishwasher is a convenience item which does not eliminate the need for a sink. With the apparent differences in water requirements for various models, it would be wise for the consumer to shop around and inquire about consumption values and cycle controls. A low water using model will also significantly reduce the home energy bill since dishwashers use only hot water.

Powell (1978) questioned several major dishwasher manufacturers to find out why they recommended a water temperature ranging from 60° to 70°C delivered to the dishwasher. The explanation was that animal fats and tallow, and everyday food soils are not soluble below 55°C. Not only do they stay on the dishes, but they can be redeposited as a waxy film on all items in the machine. Also, detergents are not soluble below 45°C and formulation of a cold water dishwashing detergent similar to those used in the laundry are not possible, as different materials and soils are involved. It was also explained that the heating element within the dishwasher would not solve the problem. The element, typically around 750 watts, is intended only to maintain the water at a high temperature and is capable of raising it only .5° to 1°C/min. Some dishwashers do, however, offer a thermostatic delay while the water is brought up to the correct temperature. But with a water heater setting of 50°C and a heat loss of approximately 1.5°C/m of pipe run, there would only be 41° to 44°C water temperature delivered to the dishwasher. This would mean a delay of some 30 minutes at the beginning of the cycle, which would be far less efficient than heating

TABLE E-1. AUTOMATIC DISHWASHERS(1)

Model & Number	Load Capacity Place Settings	Water Consumed (full cycle) litres	Cycle(2) Adjustment	Water Consumed with cycle adjustment litres	Type(3)
General Electric					
All models	12	61.3	Yes(4)	43.5	H, P
Hotpoint					
Front load models	12	54.9	Yes(5)	37.5	H
Top load models	12	61.3	No	37.5	P
Sears (Kenmore)					
7202	12	53.0	No		P
7203	12	53.0	Yes		P
7204-7205-7206	14	53.0	Yes		P
7211 through 7215	14	53.0	Yes		H
Maytag					
WU 601	—	52.0 - 62.5	Yes		H
WU 401		52.0 - 62.5	Yes		H
WU 201		52.0 - 62.5	Yes		H
WC 401		52.0 - 62.5	Yes		H
WC 201		52.0 - 62.5	Yes		H
Frigidaire Division (GMC)					
DW-DU, DW-CDU	—	55.3	Yes	33.3	H
DW-IU, DW-CIU		55.3	Yes	33.3	H
DW-CDU, DW-IM		55.3	Yes	33.3	P
DW-CIM		55.3	Yes	33.3	P
Kitchen Aid (Hobart Corp.)					
KDS-17A	14	56.4	Yes		H, P
KDI-17A	14	56.8	Yes		H, P
KDC-17A	14	51.1	Yes		H, P
KDR-67	14	56.8	Yes		P
KDD-67	14	51.1	Yes		P
KDW-7, DKA-7, KDC-7	14	45.4	Yes		P
Westinghouse(6)					
SU100P/SU400P	14	70.0	Yes(6)		H
SU500P/SU700P	14	53.9	Yes(6)		H
SC100P/SC400P	14	69.1	Yes(6)		P
SC500P/SC700P	14	53.9	Yes(6)		P
Admiral Corporation/ **Rockwell International**					
DC2456	—	50.0	Yes	33.3	P
DC2459		50.0	Yes	33.3	P
DC2454		50.0	Yes	33.3	H
DU2459		50.0	Yes	33.3	H
Speed Queen (McGraw Edison)					
DC5600	12	53.0	Yes	26.5	H, P
DC5700	12	53.0	Yes	26.5	H, P

(1) Adapted from WSSC Survey of Automatic Dishwashers

(2) For use in conserving water and energy

(3) H - home, P - home portable

(4) Except Model GSD 251

(5) Except Model HDA 312

(6) For single wash which reduces water consumption

it in the hot water tank. Since hot water for other purposes need not be at such a high temperature, it may be advantageous to install an in-line water heater ahead of the dishwasher and operate the hot water heater at a safer, more efficient temperature of 50°C.

The hot water also permits automatic dishwashers to sanitize better than handwashing. Sanitizing occurs during the final rinse stage of many machines; however, this benefit as well as the previous explanations could all be accomplished during the wash part of the automatic dishwashing cycle. It has not been explained why cold or warm water cannot be used during part of or all of the rinse operation. While the temperature change from a hot wash to a cold rinse may be harmful to some items washed, the effect of a warm water rinse should be minimal. With the free-standing portable models which simply couple on to the sink faucet, it is possible to have any desired temperature mixture of water. Providing the dishwasher does not have a thermostatic-controlled delay, which is used to bring the water up to a high temperature, the only problem would be that this is a user manipulated solution timed for the rinse part of cycle. However, there are several models that offer a "rinse-hold" button which would permit a user to change the water temperature at their convenience. For the under-the-counter built-in models, connected directly to the hot water supply line, this would not be possible. Manufacturers may in the future design models which accomplish all objectives during the wash cycle and which would connect to both the hot and cold water lines for reduced rinsing temperatures. For the automatic dishwasher, cold or warm water rinsing will not save water, but it will save energy.

Reducing the quantity of water associated with the use of an automatic dishwasher can usually best be accomplished by adjusting user habits, such as the following three suggestions from the WSSC Customer Handbook on Water-Saving and Wastewater-Reduction (revised May, 1976). Appendix G contains other ideas and suggestions for the automatic dishwasher and similar suggestions for hand washing of dishes.

1. Let the dishwasher perform its function and eliminate any unnecessary pre-rinsing.
2. Always load the dishwasher to capacity for each full cycle of operation.
3. Follow the operating instructions since a few manufacturers suggest shortening the full machine cycle time to accommodate some types of washing loads.

The widespread use of the automatic dishwasher indicates its positive acceptance and they are considered essential by many people. Water use and savings will vary from household to household. In earlier studies by the U.S. Public Health Service (1967), and Linaweaver (John Hopkins University, 1963), it was indicated that certain household water using functions were relatively independent of the number of household occupants. In accordance with these studies, Bailey et al, (1975) felt that whether dishwashing was done by hand or by automatic washer, the amount of water used is more directly related to the number of times dishes are washed than to the amount of dishes washed. However, it would seem reasonable to expect that given the fixed capacity of the automatic dishwashers, a large family would have more dishes and thus more full load operations than a smaller family. This assumes, of course, that the automatic dishwasher is always loaded to capacity for each full cycle of operation, and that allowances are made for the possibility that on some occasions an additional quantity of water might be used for washing items not put into the dishwasher. In any case, water use depends on the development of household habits in conjunction with available dishwashing facilities.

Hand washing offers the greatest flexibility in terms of water use; however, it appears that the judicious use of an automatic dishwasher need not increase water consumption. Machines which use less water and offer the greatest user control over cycle selection should be selected.

E.2 Food Waste Disposers

Food waste disposers are located in the drain line under the kitchen sink. An electric motor spins cutters that grind up kitchen wastes. Running water from the faucet is used to flush these wastes down the sewer drain.

Data on the approximate quantity of water used by an in-sink food waste disposer was presented by Watson (1963). In his survey of 31 households, the variation in disposer water use by all models of all manufacturers was not significant. The size of the family also had little effect. The one factor which did make the determination of disposer water use somewhat difficult was the difference in the patterns and duration of use prevailing in the various homes. From the survey data, Watson calculated 2.18 minutes as the average time of disposer use per day with 95% of the units being used less than 3.64 minutes per day. This average time could then be used to estimate disposer water use in any supply system by multiplying by the flow rate corresponding to the pressure prevailing at the sink faucet. For design estimates, a final 50% increase in this amount was suggested to allow for drain flushing after the disposer was turned off. Average disposer water use by this method was estimated at 26 litres per day or about 3% of the total water used in a household of four.

In a later study by Watson et al, (1967), it was observed that there was no significant increase in the total household water consumption as a result of the use of a disposer. The reason was not entirely understood, but it was suggested that with a disposer in use, less water is required to keep the sink, colander and garbage pail clean. This view is not shared by WSSC which stated that in-sink food waste disposal units use a substantial amount of water as the flushing vehicle for moving waste through cutters and into the household drainage system. They suggest reducing the use of this type of device by disposing of most garbage with other solid waste in the household trash can. Disposers also require electricity and their use adds to the grease and organic loading on sewage treatment plants, which in turn increases costs for treatment systems influenced by organic loading.

It appears that in-sink food waste disposal units will increase water consumption but with judicious use this can be negligible. Thus, their installation is at the discretion of the household since they are not an essential home appliance. When a household does feel it desirable to use an in-sink food waste disposer, water consumption can be decreased by reducing the rate of flow through the faucet. There are several kinds of flow reduction devices available, and most of the modern kitchen faucets already come equipped with some built-in flow reduction, commonly in the form of an aerator. These and other flow reduction devices are discussed in Appendix F.

E.3 Drinking and Cooking

Water usage for drinking and cooking is relatively fixed and is a very small but essential portion of total household usage. Little can be done to cut back on this usage other than reducing the amount of water wasted when performing these necessary functions. Apart from the methods of reducing flow from the faucet, which are discussed in Appendix F, user habits are the primary method of controlling wastage. Appendix G contains a number of useful hints for the kitchen, but the general theme is to pond water when washing or rinsing items and to chill water for a cool drinking supply.

E.3.1 Chilled Water Supply. Having chilled water readily available reduces the necessity of running the faucet to drain the line before a cool supply is received from the cold water line. There are several ways to have chilled water readily available, the most common and least expensive of which is to keep a bottle of water stored in the refrigerator. A more sophisticated and expensive method is to have a refrigerator with a chilled water dispenser incorporated into the door. This option is available on some of the larger, higher priced refrigerator models, and generally they include other features such as ice crushers and ice cube dispensers. The inclusion of these other convenience features along with the chilled water dispenser increases the costs of these models, over a comparable refrigerator without these features, by about $200. Milne (1977) feels potential water savings are provided by the chilled water dispensing refrigerator without noticeably increasing energy consumption, for those affluent enough to afford them. Exact savings have not been estimated and would depend very much on the water supply system and user habits.

E.3.2 Bottled Water. In some areas, bottle water has been used for drinking and cooking in addition to municipally supplied water for other uses. Bottled water is chosen by those who do not care for the flavour, purity or chemical additives of municipal water and there are a few who feel it will extend the municipal reserve if brought in from beyond the local water supply. In some areas, bottled water is home delivered and placed on a stand ready to use at a cost of about \$.10/L Many supermarkets also sell bottled water for approximately \$.13/L. With the high cost for this type of water supply, the user is very careful to avoid waste and spillage. This is similar to where all water is delivered by truck. It is doubtful if the separate delivery of bottled water would be practiced or economical for water conservation purposes alone.

E.3.3 Drinking Fountains. The drinking fountains with a built-in cooler, commonly found in offices, schools and public buildings, offers another alternative for a chilled water supply. Unless the fountain water is pre-cooled, which requires energy, the result would be the same as drawing water from a faucet. However, when drinking directly from a fountain at least half of the water is wasted, and where drinking fountains are installed, water could be saved by providing a cup dispenser. Drinking fountains should also operate by a vandal-proof spring loaded valve so they must be held open to obtain water. It is unlikely that drinking fountains will ever become common home fixtures because of their size and institutional image. Also, it is usually more practical to simply keep a container of water in the refrigerator.

APPENDIX F

MISCELLANEOUS WATER CONSERVATION ALTERNATIVES

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F. MISCELLANEOUS WATER CONSERVATION ALTERNATIVES

While much of the water consumed within a household is by essential activities that cannot be eliminated, there is equipment and several systems available which can reduce waste and make water use more efficient. Divided into two parts, this Appendix contains a review of these alternatives. The first topic is the faucet, which is the most common water-using fixture in the home. Some types of faucets or add-on equipment will conserve water and a few will increase user convenience, comfort and safety. Water flow reduction at faucets also has the added benefit of energy savings since approximately 50% to 75% of the flow is heated water (Nelson, 1977). The other topic discussed is household systems. These alternatives all involve some alteration in the conventional household plumbing, but they will provide an additional water and energy saving when used with other water conserving devices. Both faucets and household systems are summarized in Table F-1 with a list of suppliers provided in Table F-2.

F.1 Faucets

The most common type of conventional faucet controls the water flow from a supply line by means of a rubber gasket which is turned down onto a seat. The gasket is connected to a valve stem and operated by a handgrip. Depending on water pressure, the flow rate from a fully open conventional faucet will be as high as 20 to 50 L/min (Moses, 1974; Milne, 1976). With approximately 40% of the water used in the home passing through a faucet (Milne, 1976), user habits discussed in Appendix I, become an important aspect in controlling faucet water use. However, not all water use results from intended use, some results from unintended leakage. With the conventional faucet, wearing of the rubber gasket from pressing on the seat will eventually result in a leak. Regular maintenance also forms an important part of water conservation, but much of this leakage could be avoided by using washerless valves. These are valves which employ two ceramic discs rather than a washer and seat. The discs will resist water and mechanical wear and operating temperatures up to 80°C. The cost of a rubber gasket faucet ranges from \$15. to \$40. while washerless faucets are slightly more at \$30. to \$50.

F.1.1 Mixing Faucet. The mixing faucet has a single control handle that is used to adjust both the flow rate and the mixture of hot and cold water. These washerless faucets increase user convenience and reduce the wasting of water by allowing the desired flow and temperature blend to be quickly selected and adjusted with only one hand. Savings with these faucets could be as much as that claimed by the manufacturer of the thermostatic mixing valve which is 40% of the warm water used by conventional equipment (Milne, 1976). A disadvantage of the mixing faucet is that its compact size does not help to reduce its cost, which ranges from $30. to $50.

F.1.2 Spray Faucet. A faucet which also has a single control knob but delivers water in a spray similar to that of a shower head is the spray faucet. These faucets have been recently introduced into North America but are in common use in Europe, especially in public washrooms. They are capable of producing significant savings in both water and the energy required to heat the water (Gay, 1974). With spray faucets the flow rate is preset and the single control knob is used for on/off operation and temperature selection. They can operate adequately with a minimum water pressure of only 13 kPa, which is adequate for an elevated gravity tank water supply system. The faucet is compact and can use small diameter water supply lines. Flow rates are in the range of 2 to 3.5 L/min., but because of the low flow, hot water must be quickly available. It is possible, however, to use an in-line water heater, thus, eliminating the need for a hot water line to the faucet. While their low flow rate greatly reduces water use when washing under a free flowing faucet, the major drawback is that they are inconvenient for filling basins, sinks or other containers. Public acceptance of the spray faucet could be slow due to their institutional image and, therefore, their major application may be for public facilities. Their cost of approximately $45. is slightly more than a conventional faucet.

F.1.3 Thermostatic Mixing Valve. A plumbing device which is generally used to supplement a faucet is the thermostatic mixing valve. It connects to both the hot and cold water lines with a single supply line outlet leading to the faucet. The thermostatic mixing valve controls the water flow rates of the hot and cold supply lines providing a constant pre-selected water temperature, regardless of any pressure or temperature changes in the supply water lines. The mix of water is controlled by means of a sensitive bi-metal spring, composed of two metals with different thermal properties. As the water temperature rises, the two metals expand at different rates causing the spring to open and when the water cools the spring closes. The spring moves an interior mechanism which in turn controls the hot and cold water supply. By providing a constant pre-selected water temperature user convenience, comfort and safety are increased. This valve also reduces the water consuming processes of waiting for hot water, adjusting for the desired temperature, and readjusting if a pressure or temperature change occurs in either the hot or cold water lines. The manufacturer of the mixing valve claims water savings up to 40% of the warm water that would have been consumed if conventional valves were used (Milne, 1976). Costs can be reduced by centrally locating the valve and using it to control the temperature of the water supplied to a number of fixtures, providing that the same water temperature is desired at each outlet. A multiple control installation would be more appropriate for public showers or lavatory sinks. However, there is also the possibility in a household setting whether controlling multiple fixtures or just one, adjustments may have to be made when different temperature preferences are involved. The cost for a thermostatic mixing valve is approximately $70. and installation costs will vary.

F.1.4 Flow Control. When the flow rate of a faucet is higher than desired or needed, a flow control can be installed in the water lines ahead of the fixture or added onto the end of the spigot. These devices restrict water flow by means of a small diameter orifice and are either an insert or a threaded fitting. The operation and the flow rate characteristics of a pressure compensating flow control device are shown in Figures F-1 and F-2. Flow controls are available with various maximum flow rates ranging from 3 to 12 L/min. and most will compensate for pressure changes in the water supply lines producing a constant flow rate. They are inexpensive devices at $1. to $6. and are usually easily installed as a retrofit, however, some may require cutting of existing water lines for installation. Some of the newer faucets which are available incorporate a flow control in their design. With an average flow rate of 8 L/min water flow will be ample without being wasteful and water savings may be as much as 25% over conventional flow rates. A disadvantage is that it will take longer to fill fixed capacity containers such as a sink or a glass. Also, some users may feel that the flow rate is too low.

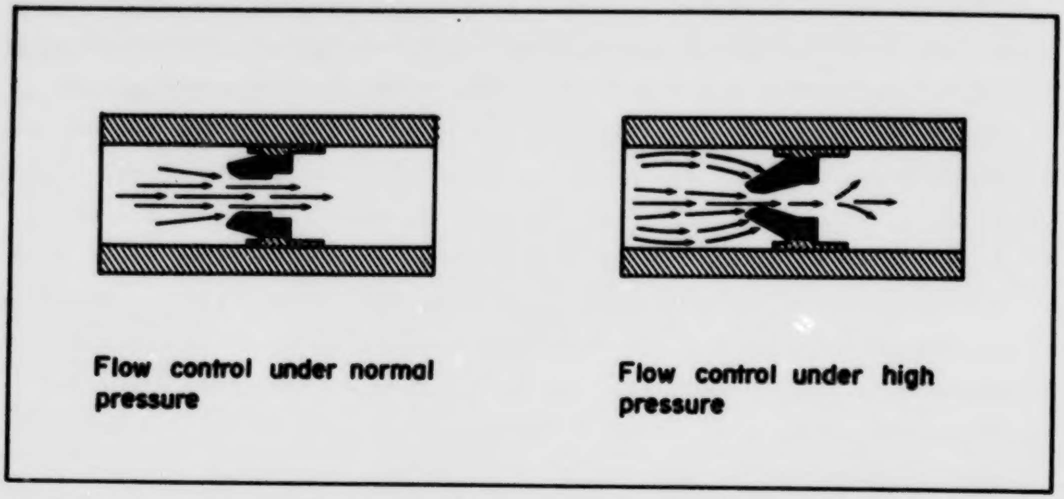

Flow control under normal pressure
Flow control under high pressure

FIGURE F-1. OPERATION OF A PRESSURE COMPENSATING FLOW CONTROL DEVICE

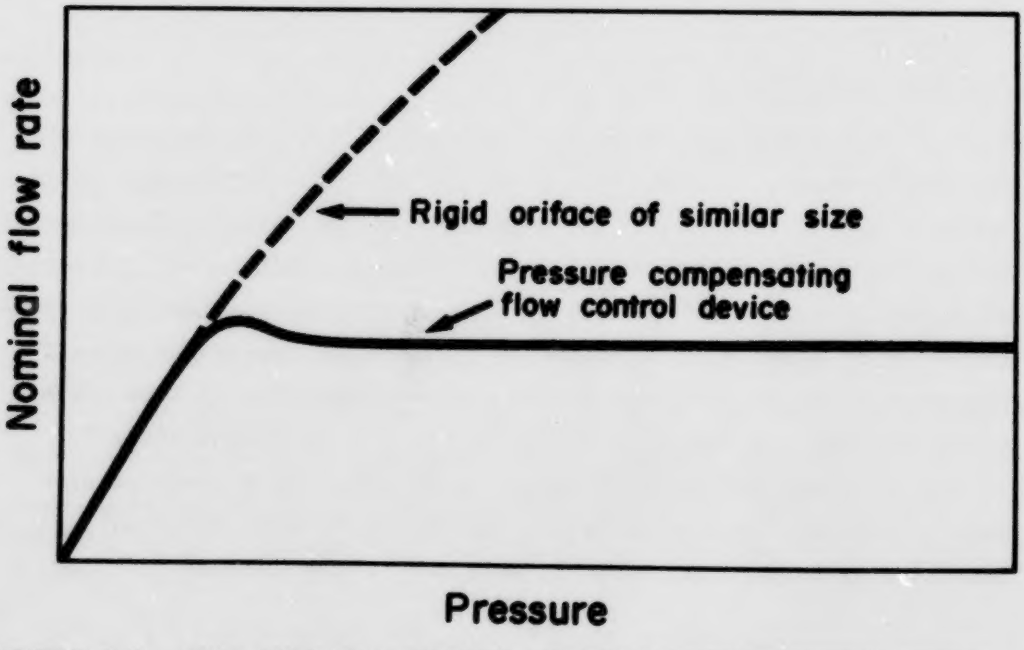


FIGURE F-2. FLOW RATE OF A PRESSURE COMPENSATING FLOW CONTROL DEVICE

F.1.5 Faucet Aerators. Aerators will also act like a flow control since they reduce the amount of water that can flow out of a faucet. They attach to the end of the spigot and give the appearance of a larger flow than is actually present by breaking up the flow and introducing air bubbles into the stream of water. The aerated flow feels gentle and greatly reduces splashing and they are commonly installed on kitchen and bathroom faucets. They are inexpensive at $1. to $5. and easily threaded on the end of the spigot, however, they may not fit all old style faucets without an adaptor. It has been estimated that aerators reduce faucet water consumption by approximately 25% (Chan et al, 1976; Muller, 1975) but Milne (1976) felt that most aerators will produce about a 50% reduction in flow. However, apart from the flow rate, user habits may determine whether a saving will be achieved with an aerator. Watson (1963) commenting on in-sink food waste disposal units stated that because aerators reduce splash, many people probably open the faucet all the way while the dispoal unit is in use. He observed, for this situation, that the flow rate of a conventional faucet at normal flow would be appreciably less than the use with an aerator. Depending on pressure, the normal flow rate with an aerator will be 10 to 25 L/min. There are water conserving aerators available for approximately $2.50, with a built in flow control which will provide a maximum predetermined flow rate at all faucet settings.

F.1.6 Self-Closing Valves. Self-closing valves will reduce wasting of water because they are on only for the time actually needed and ensure that the faucet is not left on unattended or after use. They are available in two basic types. The first is a spring loaded valve which simply shuts off the water supply immediately upon release. This type does not operate unattended and is generally not practical for household use. Separate spring loaded hot and cold faucets are also inconvenient with warm water only obtained by mixing in a sink or basin. The other type of self-closing valve are timer valves, which automatically close due to accumulated water pressure. They are usually a single faucet with a pre-set flow rate and temperature, usually incorporating a thermostatic mixing valve. Both types have water saving potential, but are used almost exclusively in public and institutional situations. Costs will range from $30. to $40.

F.1.7 Foot or Knee Valves. Similar to the self-closing valves are the foot or knee valves. A faucet valve is activated by depressing a foot or knee lever and when the lever is released it automatically returns to the off position. Their water saving potential is also positive since the water flow is on only while activated. They are commonly installed in hospitals because they do not require hands to operate and are therefore more convenient and sanitary. However, a disadvantage is that foot or knee valves must be attended to operate, which makes them generally inappropriate for household installations. There are also some which do not provide for temperature or flow rate selection. The initial cost and modifications to existing equipment is expensive, possibly requiring the services of a qualified plumber. Capital cost for a foot or knee valve will vary from $75. to $120.

F.2 Household Systems

F.2.1 Pressure Regulator. A method used to reduce the rate of water flow in all water outlets is installations of a pressure regulator on the household water service line. A pressure regulator is made up of two chambers with a rubber diaphragm between them. An adjustable spring is used to change the pressure on the diaphragm which in turn sets the household water pressure regardless of the inlet pressure. A pressure reduction in the supply line will reduce the rate of water flow through the fixtures, and for a free flowing stream of water, such as a shower, water use will be reduced. However, the lower pressure and flow rate will increase the time required to obtain a fixed volume of water. In the case of automatic dishwashers and clothes washing machines, which require a fixed volume of water, the cycle time will also be longer. Normally, pressure regulators are installed where excessive water main pressures could burst fittings or cause excessive noise, vibrations and leakage. In some utility systems, the water main pressure within zones are regulated. Pressure regulators are discussed further in Appendix I. Costs for a household pressure regulator is approximately $30. plus installation. Where existing water pressures are excessive, they will be convenient and economical.

F.2.2 Water Pipe Insulation. Water pipe insulation is a method to reduce the wasting of water at all fixtures. Insulation is fitted or wrapped around water lines, usually only the hot water line, to reduce heat loss and help maintain the temperature level of the water in the pipes. By doing so, the wasting of cooled water left standing in the lines will be reduced. A "rough" savings estimate for hot water pipe insulation of 7.5 L/person·d or approximately 3% of total water use was given by Nelson (1977). Water pipe insulation is most easily done at the time of construction as it may be difficult, expensive and/or impractical to add to some existing building water systems. However, insulation could still be installed on all the exposed piping in the foundation area of existing dwellings. Costs for insulating water lines will be approximately $1.50 to $3. per meter. If the water savings are 3% of total water use, the present value of the water savings for a typical household at piped water rates of $1. and $2./1000 L are $67. and $134., respectively, and for trucked water rates of $10. and $20./1000L, the savings are $284. and $568., respectively. There will also be some energy savings in addition. While the cost of insulating hot water lines will vary, it will, in most cases, be economical for houses on trucked systems and will be desirable for houses on a piped system.

Similar to hot water pipe insulating is hot water tank insulating. By increasing the insulation thickness on gas and oil fired heaters to 10 cm. or 18 cm., fuel savings of 21% to 25% are possible. With electric units a 5% to 11% saving is possible by increasing insulation thickness to 7.5 cm or 13 cm (Muller, 1975).

F.2.3 Hot Water Circulation. Another method which also eliminates the need to waste cooled water left standing in the line between the hot water heater and the faucet is hot water circulation. With this system, the hot water pipes in a building or in a particular area are looped back to the hot water tank and a small pump circulates water within the loop. The faucets or other water outlets tap off the loop receiving instant hot water since the water in the supply loop is maintained at the hot water heater temperature. To reduce pump operating time and heat loss, the pump can be put on a timer or thermostatic control so that it only operates intermittently. Also, insulating the pipes to reduce heat loss becomes more important because the water is maintained at a high temperature. Capital costs for this system will vary with a minimum cost of about $100. for the pump and $25. for the extra plumbing. Retro-fitting existing buildings will usually be expensive and often impractical.

F.2.4 Hot Water Return. For buildings with individual water systems, such as those served by truck systems, there is an alternate method which can be used that does not require a circulation pump. This method requires a return line from each faucet to the cistern with a drain valve located on that line at each faucet. When this valve is opened, the water pressure flushes the cooled water in the hot water supply line down the return line. When hot water is received at the faucet, the drain valve is closed and then hot water can be obtained from the faucet. Thus, the cooled water which is often run down the drain has been returned to cistern and saved for future use. While a makeshift version of this method has been used, some innovation in the development of special fittings for convenient operation is required. The reduction in water use with either the circulating or return hot water system will be at least that of insulating the hot water pipes, 3% of total household water use. The economic benefits will also be similar, however, either system would only be economical for houses served by a truck system, particularly if a return rather than a circulating system was used.

F.2.5 Instant Hot Water Tap. In situations where hot water circulation is impractical an alternate method may be an instant hot water tap. This tap is in addition to the existing faucets. Hung under the counter and connected to this tap is a small insulated hot water heater. The electrically powered heater will produce about 11 to 19 L of water per hour at 90°C, or 22 to 42 L at 45°C. The instant hot water tap has found useful application in the kitchen where it is used to make quick cups of coffee, tea, soup, gravies and other similar items where otherwise large quantities of water may have been used and wasted. In other locations in the home it can save the cooled water normally run off before a warm supply is received. A disadvantage is that scalds can result if the user is not careful. Cost for an instant hot water tap is about $125.

F.2.6 Recycle Systems. A household system not found appealing to many, but reduces the total water requirement to zero or minimal is a recycle system. The total concept is where all household wastewater is collected and treated for reuse. However, the inclusion of blackwater (toilet wastes) serves to increase capital and operating costs and, therefore, some systems only recycle greywater. There are also some which may not recycle for drinking and cooking purposes, in which case an alternate supply of water is necessary. Treatment methods for these systems may include biological, chemical precipitation, filtration, carbon adsorption, reverse osmosis, distillation, disinfection and/or others. This type of complex technology is beyond most householders capabilities to maintain. Recycle of wastewater, except for the purpose of toilet flushing, is a health hazard and as mentioned previously not aesthetically acceptable by many. In addition, the system requires energy, chemicals and scheduled servicing by qualified personnel. It also takes up space and may require an alternative system for emergencies. Costs for a recycle system will range from $2500 for systems which recycle only wash water, for toilet flushing and lawn watering to $5000 for a complete packaged recycle system. Wastewater reuse alternatives are discussed in more detail in Appendix G.

Table F-1 Miscellaneous water conservation alternatives

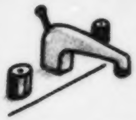
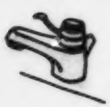
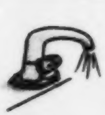
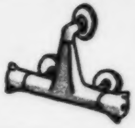
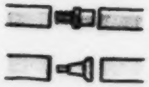
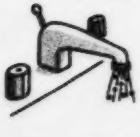
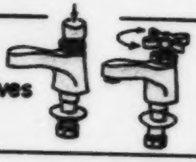
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Conventional faucets 	Water flow from supply line is controlled by rubber gasket which is turned down onto a seat. Gasket is connected to valve stem and operated by a handgrip. Available with single spigot or separate hot and cold faucets.	Valve controls water flow rate. Washerless valves with ceramic discs instead of rubber resist water and mechanical wear and operating temperatures up to 80°C.	High unrestricted flow rates. Wearing of rubber gasket type results in water loss due to leakage.	H&C water supply lines.	20 - 30 Lpm	$15 - $40 Washerless $20 - $30	Depends on cost of water and hot water heating.
Mixing faucets 	Single faucet with one control handle that is used to adjust both flow rate and temperature of water.	Desired flow and temperature can be quickly selected and adjusted with only one hand, thereby reducing waste. Compact.	More expensive than conventional.	Same as above.	Reduces waste	$30 - $50	Same as above.
Spray faucets 	Single faucet which delivers water in a spray, much like a shower head. Flow rate is preset and control knob is used for on/off operation and temperature selection.	Minimum pressure requirement of 13 kPa ideal for gravity tank systems. Compact and can use small diameter water supply and drain lines. Possible to use an in-line water heater eliminating need for hot water line.	Inconvenient for filling containers due to very low flow rate. Institutional image as they are commonly installed in public restrooms. Cost slightly more than comparable conventional faucets.	Same as above.	2 - 3.5 Lpm	$45	Same as above.
Thermostatic mixing valves 	Temperature changes from the hot and cold water supply lines are controlled by means of sensitive bi-metal spring. Two metals expand at different rates causing spring to move interior mechanism which controls the hot and cold supply lines, thus, maintaining a constant ratio of hot and cold water. Has two control knobs; one for temperature selection and the other controls the rate of water flow.	Provides constant pre-selected water temperature irregardless of flow (pressure) or temperature changes in hot or cold supply lines. Increases user convenience, comfort and safety by reacting quickly to supply line temperature changes. One valve can control multiple water fixtures.	Expensive and generally used to supplement other faucets.	9.5mm H&C water and supply line to faucet.	Savings are up to 40% of that used by conventional faucets.	Approx. $70	None
Flow controls 	Reduce water flow rate by means of small diameter orifice in the supply lines ahead of fixtures or on end of spigot. Are either an insert or a threaded fitting. Most will compensate for pressure changes in water supply line to produce a constant flow rate.	Reduces flow rate where they are higher than desired or needed. Inexpensive and usually easily installed as retrofit. Some faucets have them built in. Available with various maximum flow rates.	May require cutting of existing water lines to install in-line type. Some users may feel flow rate is too low. Takes longer to fill and no water savings when filling containers such as a glass or bathtub.	Threads or inserts into supply line.	8 - 12 Lpm Typically 10 Lpm	$1 - $6	None
Aerators 	Attaches to end of spigot and gives appearance of larger flow than actually present by breaking up flow and introducing air bubbles into the stream of water.	Restricts flow a little, however, main advantage is water use is reduced due to illusion of larger flow. Aerated flow feels gentle and greatly reduces splashing. New faucets generally equipped with an aerator but are inexpensive and easily installed on end of spigot of existing faucets. Some aerators have built in flow control increasing water conservation.	May not fit all old style faucets without an adapter. Reduces flow rate slightly.	Threads onto end of faucet.	10-25 Lpm	$1 - $5	None
Self closing valves 	Spring loaded valve type, simply shuts off water supply immediately upon release. Timer valves are usually a single faucet with preset flow rate and temperature which automatically close due to accumulated water pressure.	Reduces waste since on only for time actually needed and ensures it will not be left on unattended or after use. Can be used with thermostatic mixing valve.	Do not operate unattended and therefore generally not practical for households. Separate spring loaded hot and cold faucets are inconvenient and warm water can only be obtained by mixing in bowl or container. Do not have temperature or flow rate selection.	H&C water supply lines.	Reduces waste	$30 - $40	Depends on cost of water and hot water heating.

Table F-1 Miscellaneous water conservation alternatives (continued)

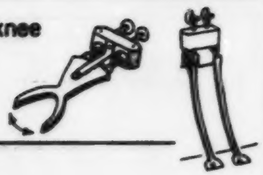
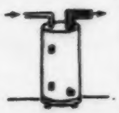
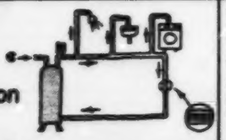
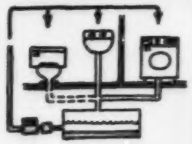
	Principle of operation	Advantages	Disadvantages	Hookups required	Consumption	Approximate cost	
						Capital	Operating
Foot or knee valves 	Faucet valve is activated by depressing a foot or knee lever and when released automatically returns to off position.	Reduces waste since water is on only when activated. Does not require hands to operate, therefore is convenient and sanitary.	Initial cost and modifications to existing equipment is expensive. Some do not allow temperature or flow rate selection. Must be attended to operate.	Mounting on floor or cabinet and controls to H&C water supply lines.	Reduces waste	$75 - $120	None
Pressure regulator	Adjustable spring is used to change pressure on a rubber diaphragm which in turn maintains the building water pressure at a preset value below the water main pressure.	Used where excessive water main pressures could burst fittings or cause excessive noise, vibration and leakage. Reduces water use and waste since maximum flow rate is reduced. Provides constant water pressure to building.	Lower pressure and therefore flow rate will increase time to obtain fixed volume of water.	Connects to building water supply line.	Saves water in all water outlets.	$30	None
Water pipe insulation 	Insulation is placed or wrapped around water lines, usually hot water only, to reduce heat loss and help maintain temperature level of water in pipes.	Reduces heat loss and rate of cooling of water in pipes thus reducing wasting of water left standing in lines.	May be difficult, expensive and/or impractical to add to some existing water systems.	None	Approx. savings of 7.5 L/person-d	$1.50 - $3 per meter	None
Water circulation 	Water pipes in the building or particular area are looped back to hot water tank and a small pump circulates water within the loop. Buildings with individual water systems only need a return line from each faucet to the cistern and a valve to allow draining. Faucets or other water outlets tap off of the loop. Usually only done for hot water pipes.	Eliminates need to waste cooled water standing in line between the heater and faucet before hot water is available. Provides hot water instantly since supply loop is maintained at hot water heater temperature. Circulation pump can be put on timer or thermostatic control to reduce heat loss and pump operating time.	Retrofitting existing systems may be impractical. Increased heat loss particularly for un insulated pipes and where circulation pump is not on a timer. Circulation of water requires a pump.	Circulation pump (electricity) and return piping.	Reduces waste	$100 pump $25 plumbing	Nominal power for pump.
Recycle systems 	Household wastewater is collected and treated for reuse. Some systems only recycle greywater and may not recycle for drinking and cooking purposes. Treatment methods may include biological, chemical precipitation, filtration, carbon adsorption, reverse osmosis, distillation, disinfection and/or others.	Reduces total water requirements to zero or minimal. Building can be independent of water and sewer systems.	Very high capital and operating cost. Complex and high technology beyond most householders capabilities to maintain. Recycle of wastewater, except for toilet flushing, is a health hazard and is not aesthetically acceptable by many. Requires energy, chemicals and scheduled servicing by qualified personnel. Takes up space and may require alternative system for emergencies.	Electrical for treatment system and pumps, recycle piping and standby system.	Depends on system.	$2500 - $5000	Cost of chemicals and power requirement. Cost of recommended monthly servicing. Cost for fresh and makeup water.

Table F-2 Miscelaneous

Supplier	Flow Control: In water line	Flow Control: Incorporated in faucet	Flow Control: Added upstream of fixture	Faucet aerators	Specialty faucets: Spray	Specialty faucets: Mixing	Specialty faucets: Timer	Pressure regulating devices	Hot water pipe insulation	Lawn watering	Others
American Standard 80 Ward Street Toronto, Ontario M6H 4A7 Tel. (416) 534-3521		●					●				
Bartle and Gibson Co. Ltd. 7214 Fort Road Edmonton, Alberta T5B 4E8 Tel. (403) 474-8991 Distributors of Kohler products		●									
Canadian Johns-Manville Co., Ltd. 565 Lakeshore Road Mississauga, Ontario L5G 1H9 Tel. (416) 278-7211									●		
Cash, A.W., Valve Mfg. Corp. 666 East Wabash Avenue Decatur, Illinois U.S.A. 62525 Tel. (217) 422-8574								●			
Crane Canada Limited 5800 Cote de Liesse Road Montreal, Quebec H4T 1B4 Tel. (514) 735-3592			●			●	●				
Eljer Plumbingware Wallace Murray Corporation Room 1230 Two Pennsylvania Plaza New York, New York U.S.A. 10001 Tel. (212) 244-8715				●							
Gerber Plumbing Fixtures Corp. 4656 West Touhy Avenue Chicago, Illinois U.S.A. 60646 Tel. (312) 675-6570		●									
Laddie Loven Trans Atlantic Import Co. Ltd. 4806-51 Ave. P.O. Box 6023 Wetaskiwin, Alberta T9A 2E8 Tel. (403) 352-4204 Distributor of Beacon Valve products	●		●								

Table F-2
(cont')

Supplier	Miscelaneous										
	Flow Control			Faucet aerators	Specialty faucets			Pressure regulating devices	Hot water pipe insulation	Lawn watering	Others
	In water line	Incorporated in faucet	Added upstream of fixture		Spray	Mixing	Timer				
MacKay-Morton Limited 50 Myrtle Street Winnipeg, Manitoba R3E 2R2 Tel. (204) 786-5891 Distributor of Dole Flow products			●			●				●	
Merwin Manufacturing, Inc. P.O. Box 509 Dunkirk, New York U.S.A. 14048 Tel. (716) 366-4103				●							
Metro Watersavers P.O. Box 4306 South Edmonton, Alberta T6E 4T3 (403) 436-1720				●							
Moen Faucet Division 377 Woodland Avenue Elyria, Ohio U.S.A. 44035 Tel. (216) 323-3341		●		●							
Noland Company National Accounts 2700 Warwick Blvd. Newport News, VA. U.S.A. 23607 Tel. (804) 244-8441			●								
Ny-Del Corporation 740 E. Alosta Avenue Glendora, California U.S.A. 91740 Tel. (213) 335-2213				●							
Savway Dual Flush Co. 930 Clarkson Avenue Brooklyn, New York U.S.A. 11203	●			●							
Sexauer, J.A., Inc. 10 Hamilton Avenue White Plains, New York U.S.A. 10601 Tel. (914) 682-8600			●	●							
Simpsons-Sears Limited 222 Jarvis Street Toronto, Ontario M5B 2B8 Tel. (416) 861-9111										●	

Table F-2
(cont')

Supplier	Miscelaneous										
	Flow Control			Faucet aerators	Specialty faucets			Pressure regulating devices	Hot water pipe insulation	Lawn watering	Others
	In water line	Incorporated in faucet	Added upstream of fixture		Spray	Mixing	Timer				
Tempflow Mfg. Co. Inc. P.O. Box 187 Prairie Grove, Arkansas U.S.A. 72753 Tel. (501) 846-3318						●					
The Toro Company Irrigation Division P.O. Box 489 Riverside, California U.S.A. 92502 Tel. (714) 688-9221										●	
T&S Brass & Bronze Works 128 Magnolia Ave. Westbury, L.I., New York U.S.A. 11590											*●
Ultraflow Corporation P.O. Box 2294 Perkins Industrial Park Sadusky, Ohio U.S.A. 44879 Tel. (419) 626-8182						●					
Walker Crosweller & Co. (Canada) Ltd. P.O. Box 148 Markham, Ontario L3P 3J5 Tel. (416) 297-2173					●						
Waterwise Products P.O. Box 2781 Yellowknife, N.W.T. XOE 1HO Tel. (403) 873-5271				●							
Watts Regulator Co. 760 Tennessee Street San Francisco, California U.S.A. 94107 Tel. (415) 648-2566								●			
Whedon Products, Inc. Box U, Station A 2074 Park Street Hartford, Conn. U.S.A. 06106 Tel. (203) 232-9877				●							

* Foot pedal control for faucets

Table F-2
(cont')

Supplier	Miscelaneous										
	Flow Control			Faucet aerators	Specialty faucets			Pressure regulating devices	Hot water pipe insulation	Lawn watering	Others
	In water line	Incorporated in faucet	Added upstream of fixture		Spray	Mixing	Timer				
Zin-Plas Corporation 1007 North Division P.O. Box Q Grand Rapids, Michigan U.S.A. 49501 Tel. (616) 454-9441				●							
Zurn Industries, Inc. Hays Fluid Controls Division Corner 12th & Plum Streets Erie, PA U.S.A. 16512	●							●			

APPENDIX G

WASTEWATER REUSE

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G. WASTEWATER REUSE

The reuse of water can significantly reduce water demands and in a few cases all but eliminate the need for a water supply and sewage collection system. In some situations, the autonomous aspect may be necessary or at least very attractive, while for others the economic benefits of reduced water use and energy requirements may be prominent. The potential pollution and health hazards of the effluent from buildings with reuse remains the same unless the recycle system incorporates some form of treatment and sludge management. These latter systems can reduce or practically eliminate pollution of the local environment. The benefits of reuse are high; however, the high costs, technical problems and public acceptance have generally limited the application of reuse to demonstration projects and specific aerospace and military type projects.

G.1 Public Acceptance

In many heavily populated and industrial areas wastewater discharged into rivers is reused downstream. The receiving water quality is improved through dilution, natural purification and water treatment before use. This can also be achieved by advanced wastewater treatment but such a direct reuse of wastewater is much more repugnent to most of the general public. The use of wastewater for irrigation is relatively easily accepted but feelings of aversion are prevelent when renovated wastewater is used for purposes that involve direct body contact (Milne, 1976).

Attitudes towards reuse of wastewater that has been treated to water quality standards were surveyed by Bruvold and Wand (1972). Most of the 1000 Californian's questioned accepted reclaimed water for public and residential lawn watering but it was rejected by 5% for toilet flushing; 22.8% for laundry; 54.5% for cooking; and 56.4% for drinking. The most frequent reasons for rejection were psychological repugnance and concern over purity. Ecological, environmental or cost considerations were not significant determinents of the response but acceptance did increase with education. After testing a residential washwater reuse system, Cohen and Wallman (1974) found that 67% of those involved in the demonstration project accepted reuse for toilet flushing and 50%

were willing to continue to use it for lawn watering. Attitudes towards reuse can be altered. A survey by Wilkinson (1975) found that 40% of Americans would use recycled wastewater if the community health authorities said it was safe and 85% of Denver's residents said they would drink recycled water if its quality was the same as the present supply.

Wimmer (1974) is much more pessimistic about reuse on practical, economic and public health grounds. He points out that renovated wastewater is essentially man made and the desirable or optimal concentration of trace metals and minerals in terms of long term health effects have not been established. Shuval (1977) questions whether public health is protected by drinking water standards that were not conceived with reuse in mind. Designers and public health authorities must give their approval and therefore must bear the responsibility for adverse health effects. There is also the real danger that the complex equipment and monitoring safeguards could malfunction resulting in a health hazard.

G.2 Types of Reuse

Reuse of wastewater can mean many things depending on the characteristics of the wastewater and the purpose it is used for. There is a significant distinction to be made between greywater which does not contain human waste, blackwater which is only the toilet waste, and wastewater which is mixed. In some cases, a distinction is made for greywater which contains kitchen waste, particularly if an in-sink garbage grinder is used. For each of these categories, the physical, chemical and bacteriological qualities of the wastewater are different, thus, the possible uses and the method and level of treatment are greatly influenced. Greywater contains most of the phosphorous and generally about half of the environmental pollution potential and is not bacteriologically safe. Blackwater is high in nitrogen content and contains the majority of pathogens and is a health danger.

Recycled wastewater should not be aesthetically objectionable, cause odours, stain fixtures, cause foaming or clog plumbing and pumps. Certain uses also have specific requirements and physical, chemical and bacteriological quality limits. Therefore, the degree of treatment required before reuse depends upon the intended use. One category of reuse is the direct reuse within the same function such as a recirculating toilet, a suds saving washing machine, a recirculating shower, or a swimming pool. The more commonly thought of recycling systems involve reuse for a different function. Perhaps the most often proposed of these is the reuse of greywater for toilet flushing. Recycle to laundry requires a bacteriologically safe water and renovated water for bathing or other uses involving body contact should meet the drinking water quality standards. The reuse of wastewater, even only greywater, for contact and ingestion such as bathing, cooking and drinking requires much more intensive treatment and fail safe disinfection.

Regardless of use, renovated wastewater is a public health hazard and must be used with caution. Wastewater that contains toilet waste is particularly dangerous and generally requires a treatment, effort to an order of magnitude beyond that necessary for greywater for the same use.

G.3 Technology

The treatment system required depends very much upon the type of wastewater and the intended use. To minimize the treatment requirements water can sometimes be cascaded in a sequence of uses which require progessively lower quality water. An example of this is the reuse of washwater for toilet flushing. Unfortunately, in many cases it is impractical to have multi-treatment systems, therefore, the one treatment system used must provide a water quality that is good enough for the most stringent use planned.

Recycle technology includes and often combines the systems used in wastewater and water treatment. Much of the technology for such systems has come from research into advanced wastewater treatment to achieve "zero discharge" (Culp and Culp, 1971), autonomous housing (Besik, 1974), aerospace life support systems (Hypes and Collins, 1974), military requirements (Brown et al, 1975) as well as other specialized areas.

The most acceptable and in many ways the easiest reuse is for toilet flushing. Nelson (1977) reported that during the recent drought in California many residents that were rationed collected washwater for direct use for toilet flushing and watering plants and lawns. Guidelines were issued on this practice which was considered a health hazard and only recommended for an emergency situation. Washwater was also used without treatment for the flushing of vacuum toilets and to recharge recirculating toilets in a washcar serving an isolated work camp (Given and Chambers, 1976). Bailey et al, (1969) reviewed the possibilities and requirements for reuse and in a follow-up study Cohen and Wallman (1974) demonstrated the reuse of bath and laundry washwater for toilet flushing and lawn sprinkling. Three different systems consisting of sedimentation, storage, filtration and disinfection were tested. Household water savings were 350 L/d corresponding to an overall total water use reduction of 26%. They make recommendations for a prototype diatomite filter system which they estimated would have a capital cost of $400. and a total annual cost of $43./a in 1974. A similar system was installed and tested by McLaughlin (1975) for an estimated $500. He concluded that with adequate settling the most expensive item, the filter ($150.), could be reduced or even eliminated. Depending on the degree of sophistication, the homeowner will have to operate and maintain such a system. A commercially available package system consists of coarse straining, chlorination, filtration and storage of treated water. The capital cost is approximately $2500 and annual operating costs are estimated at $50 per year, primarily for filter cartridges. Milne (1976) suggests that if a toilet without a tank, such as a flush valve toilet were used along with plumbing that would not clog, then the expensive filtering of washwater could be eliminated.

The reuse of washwater has been studied as part of the aerospace program. Filtration followed by reverse osmosis has been the most used process (Putnam et al, 1973). A 5 L/min unit required 0.02 kW·h of electricity per litre. Laundry water treatment by reverse osmosis was also evaluated for shipboard use by Adamson and Pizzino (1974) and a simple precipitate system was evaluated by Lard et al, (1976). Because of a limited water supply during the winter, two central facilities for small unserviced communities that were constructed as part of the Alaska Village Demonstration Project included the collection and treatment of washwater for laundry and toilet flushing (Puchtler et al, 1976; Reid, 1977). The package physical-chemical treatment plants required considerable modification and detailed operator attention. They have recommended that a new facility use powdered activated carbon because of the difficulty with bacterial growth in carbon columns and that the incineration of sludge be eliminated due to its high energy cost, regardless of heat recovery devices. The project has had many difficulties but reuse for laundry has been demonstrated and with the use of a limited amount of fresh water there has been a noticeable improvement in health within the community.

A number of systems have been proposed which recycle water within a building or household for more than just toilet flushing. Smith (1973) reviewed the autonomous housing proposals which used many types of treatment including reverse osmosis and distillation. The "CANWEL" system is an integrated system to serve an apartment building (Bisik, 1974). In one system, all water is recycled and in the other a separate fresh water supply system is provided for drinking and cooking. The treatment system proposed consists of screening, biological oxidation, chemical treatment, aeration, filtration, breakpoint chlorination, dechlorination, reverse osmosis, activated carbon polishing and disinfection. Although such a system was proven feasible it is complex and Bisik stated that the technology with the efficiency and reliability required for this application and for a relatively small size plant was not available. A recycle system for a small mobile military group or possibly an arctic community was assessed by Brown et al (1975). Although complete recycle was feasible with present technology, it was decided to supply water for drinking and cooking separately. They evaluated a number of processes and found that for blackwater wet air oxidation was technically superior than biological or physical-chemical treatment. This would be followed by the addition of greywater and lime treatment, filtration, ammonia stripping, reverse osmosis and ozonation. One man would be required to run the plant which would serve 100 persons.

A package recycle system designed for total household reuse is available. It consists of biological treatment, filtration, activated carbon adsorption, ion exchange and ultra violet radiation. The system and effluent are continuously monitored. The system is the size of a small car and costs about $6000. plus a monthly service fee of about $30., where available.

G.4 Application

There are a number of technical and practical as well as economic and social problems with reuse. The former are accentuated in the small isolated communities of the north; however, the benefits may be higher. The concept of recycling wastewater, particuarly within the home, is still relatively new. The equipment to accomplish this is available but in many cases it is impractical, unreliable and too expensive. This does not mean that one can or should rule out reuse. In some situations recycling may be a viable and cost-effective alternative. New technology or innovations to improve reliablility while reducing the maintenance requirements can be anticipated. The key questions with regard to reuse are: does it provide benefits that can not be achieved easier and more cost-effectively by some other method and; what degree of reuse is appropriate and cost-effective?

It is hard to imagine an earthly situation where water is in such limited supply that the use of renovated wastewater for drinking and cooking would be necessary or a significant benefit. This quantity of water is very small and the high level of sophisticated treatment and monitoring systems required to protect public health and achieve public acceptance greatly increases the capital and operating costs of a recycle system. Also, the introduction of human waste into a recycle system appears to be unnecessary in many cases and often significantly increases the costs. It is only applicable for autonomous building situations where a major goal is the elimination of discharges to the environment.

G.4.1 Reuse versus Conservation. Unless complete autonomy or zero pollution is a prerequisite, limited or selective recycle appears to be more practical and attractive. Smith (1973) analyzed the economics of recycling compared to water conservation and concluded that "a change in equipment and habit could eliminate the need for water recycling, except for some local recycling within a particular water use function itself, and this seems the most economical alternative". Unfortunately, few other authors have looked at water conservation versus or in conjunction with reuse to minimize the capital cost and operating requirements. For example, the most proposed application is reuse for toilet flushing; however, the use of any number of low water use toilet alternatives can provide nearly the same flow reduction benefits with simpler technology. In most cases, this would make reuse uneconomical unless perhaps the recycle system was sized for the reduced volume of water required and the toilet was selected and the system designed such that treatment before reuse was not required. There are also toilets available that have no water requirements and incinerating and compost toilets produce only a dry stable residue for disposal. As another example, the use of a hand-held shower unit or an air assist shower system can reduce bathing water requirements by over 90% compared to a conventional shower and these alternatives may be more acceptable and are certainly less complex than recyle. The remaining practical use of renovated greywater is for laundry. Front load washing machines would reduce water requirements by about 40% compared to a conventional top load washer but if the other water conservation measures previously mentioned were implemented this would make laundry the major single user of water. Some authors have suggested the use of ultrasonics to reduce the laundry water requirements. If this technology is not available then it appears that the most practical and economical application for reuse is for laundering.

G.4.2 Implementation. The implementation of recycling, for whatever use, requires changes in the normal building plumbing system and space for the treatment equipment and storage tanks. Therefore, it would be difficult, expensive and often impractical to initiate recycle in an existing house or building.

Most of the reuse systems require complex equipment and some degree of operation and maintenance and unless the system is very simple this should not be left up to the individual. With present technology, except for the reuse of washwater for toilet flushing, recycling in the individual home does not appear to be practical. Government or group owned and operated equipment would be an advantage in terms of ensuring maintenance and repairs by trained personnel. In isolated northern communities it is often difficult to find the technical expertise necessary to operate complex systems although the Alaska Village Demonstration Project did show that with financial and technical assistance the local people could operate a complex recycle treatment plant. Since a system within a large building, hotel, school, laundromat or central facility complex would have maintenance personnel available, these situations are the more attractive applications for reuse, particularly in the north.

G.5 Economic Analysis

Each application of reuse requires a different treatment system depending upon the type of wastewater to be renovated and its intended use. Also, the technology for reuse is still developing and capital and operating costs are usually not available and often existing systems are prototypes or makeshift demonstration technology which rely on the user to operate them to some extent. It is possible, however, to estimate the benefits of a reuse system in terms of the reduced water demand and energy required for hot water heating. Such an analysis would disclose the maximum benefits and, therefore, the maximum expenditures that can be put towards an economical reuse system. Often this will indicate the practicality of pursuing technology to meet the objectives while still remaining economical.

The design, capital and operating costs of a recycle system will depend to some extent upon the capacity required and this can be reduced by various water conservation devices, which in turn have a cost. The most attactive and lowest cost system will, therefore, probably incorporate conservation and reuse. For example, renovating wastewater for recycle to a 6 L toilet may be more economical than to a 20 L toilet or perhaps a household reuse system that incorporates a compost toilet and reuse of washwater may be attractive. Because of the almost unlimited possibilities, it is very difficult to assess the economics to indicate the lowest cost system.

The obvious benefits of reuse are the reduction in water demand and possibly some reduction in hot water heating. Given the average unit cost for these, the benefits can be estimated; however, often there are other reasons for instituting reuse. For example, the autonomous building may not require any water or sewerage infrastructure. For any single such building in a community, the benefits may be calculable but the real benefits may only be realized when all buildings are autonomous and no utilities infrastructure is required. For isolated buildings or facilities, the benefits are more obvious and can be estimated on a site-specific basis. For some, the independence and security of self-reliance is the real benefit, and this is, of course, difficult to put a dollar value on. Another benefit of some reuse systems, particularly the autonomous building, is that there may be "zero" pollution. The overall benefits of this may be greater than the alternative cost of central sewage treatment, particularly if the receiving environment is not considered to have an assimilative capacity. In northern areas, the assimilative capacity of receiving waters is relatively lower than in similar temperate situations, particularly during the long winters when water bodies are ice covered. On the other hand, there is a very low population density and level of development. Therefore, environmental benefits should not be presumed or overestimated without a site-specific assessment.

As indicated above, the major benefits of a complete recycle system within buildings in a community are only realized when no utilities infrastructure is required. Alternative fire protection systems would be required to eliminate the need for a water main and the very small volume of make-up and fresh water required would probably best be delivered by truck. Therefore, it would be unrealistic to consider the economic benefits of largely autonomous buildings in terms of the unit cost of water that would normally have been used. Limited reuse, such as for toilet flushing only, may be evaluated this way if the marginal cost of water is used in the analysis. Buildings and communities that are served by truck systems are already partly autonomous and the economic benefits of conservation, including reuse can be estimated from the unit costs for water delivery, sewage pumpout and other water supply and sewage disposal costs.

If the benefits of reuse can be derived from a unit cost then the present value of the savings is:

Present Value of Water Savings = Present Value Factor X (Water Savings (L/d) X (365) X (Cost of Water ($/1000 L) ÷ 1000)

The Present Value Factor for a discount rate of 10% and a period of 10 years is 6.144.

Therefore:

Present Value of Water Savings = 2.24 X Water Savings (L/d) X Cost of Water ($1000 L)

Note that a 20 year period would increase the benefits by 30%.

If the warm bathing and laundry wastewater is reused there will be some benefit in terms of a lower temperature increase required to supply "fresh" hot water to these functions. If the wastewater has a temperature of 20°C and the normal raw water is at 5°C, the benefits are a 15°C decrease in the heating requirement in the hot water demand. If electric heating is assumed, the present value of these savings at 10% over 10 years is:

Present Value of Energy Savings = 39 X Hot Water Savings (L/d) X Cost of Energy ($/kW·h)

G.5.1 Toilet Reuse. The installed cost, operating requirements and economic analysis of the toilet alternatives are presented in Appendix B, Table B-4. A toilet reuse system, to be economical, must have a present value less than that of the most economical alternative. For example, at a piped system water and sewer rate of $1/1000 L and 5840 uses per year, a new installation of a European 6 L toilet would have a total present value of $546, of which $216 is for water and sewer charges. It appears unlikely that a toilet recycle system which must include as a minimum a toilet, greywater storage tank, pump and plumbing could be installed for less than $546. Any treatment of operating costs would certainly make a toilet reuse system out of the question. This conclusion is contrary to some previous papers, principally because they compared a reuse system to a conventional toilet.

For truck systems, the most economical practical alternative is the recirculating toilet which already incorporates reuse. For a household of four at 5840 uses per year when water and sewage unit cost is $10/1000 L, the total present value of costs associated with use of a recirculating toilet is $718., of which only $72 is for water and at $20/1000 L it is $790. Again, it would be difficult if not impossible to install even the simplest greywater reuse system for these costs. The recirculating toilet could be recharged with collected greywater by hand but it hardly seems worth the effort for the limited benefit of $72 which is equivalent to only $12/a. If a more conventional toilet is desired or required, the most economical is the European 3 L with a present value of $1400 and $2472 at the lower and higher water and sewer rates. It may be possible to install a greywater reuse system for such a price, however, it is questionable whether such a reuse system is more aesthetic and desirable than a recirculating toilet.

Therefore, for both piped and trucked systems reuse to toilets only is not economically attractive compared to other low water use alternatives. This is certainly true for households and it is likely that the same would apply for a multiple installation.

G.5.2 Bathing Reuse. The operating costs of bathing alternatives are presented in Appendix C, Table C-1. From this table it can be seen that the low flow shower head provides considerable savings over tub bathing and conventional showers and the use of a hand-held self-closing shower unit or an air assisted shower system can reduce bathing water requirements even further.

For households on a truck system at low and high rates of $10/1000 L and $0.05/kW·h and $20/1000 L and $0.20/kW·h the present value of the benefits of reuse would be approximately $880. ($143/a) and $1830 ($300/a), respectively, if normal usage had been reduced by one third through the use of a low flow shower head. Considering the high level of treatment and safeguards necessary for the recycle of even only greywater for a body contact application such as bathing, it appears that a reuse treatment system would be too costly to be economical. If water is very expensive or in limited supply, an inexpensive hand-held self-closing shower system can be used. Although it is less convenient than a constant flowing shower head, adequate bathing can be attained with as little as 10 L of water and some people may prefer this to using renovated wastewater. If this system were used the benefits of reuse would be only one quarter of that presented above and reuse would certainly be uneconomical.

G.5.3 Laundry Reuse. The initial and operating costs and an economical analysis of laundry alternatives is presented in Appendix D, Table D-5. From this it can be seen that the low water use front load washer is the most economical alternative for new installations; however, at high water, sewer and electrical rates and high usage, the annual costs are still quite high. For example, the present value of benefits of reuse for low ($10/1000 L and $0.05/kW·h) and high ($20/1000 L and $0.20/kW·h) truck rate situations are $7.48 and $15.27, respectively, per wash load per year.

Considering the capital and operating requirements of a treatment/reuse system, a household which may only do 100 to 250 wash loads per year, may not find treatment and reuse attractive. However, a suds-saver for the household washer would be economical and practical.

A central laundraumat or an apartment building serviced by a truck system may find that reuse is economical. For example, if reuse is incorporated into a laundraumat that serves 100 persons requiring one wash load per person per week, the water, sewer and hot water expenditures could be reduced by $39,000 ($6300/a) and $80,000 ($13,000/a) at the low and high truck rates, respectively. A central laundry, either commercial or government operated or subsidized, would appear to be economically attractive, particularly if it serviced a large portion of a community. Although some people would find this inconvenient, it would greatly benefit those without a laundry machine.

Without a detailed analysis it appears that a central laundry with a treatment system for reuse is economically attractive in communities with high unit water cost such as those serviced by truck systems and/or those with a limited water supply. Designs and technology to facilitate such systems are worth pursuing and the development of a simple system would find application.

G.5.4 Greywater Reuse. It appears that total reuse within households is seldom economical or practical and that reuse for individual functions is also not very attractive. A remaining alternative is the limited reuse of treated greywater for the toilet, laundry and bathing with fresh water supplied to all sinks. The recycled water would have to meet body contact water quality standards.

For a typical household of four with conventional plumbing and serviced by truck, the water savings possible with greywater reuse would be 320 L/d thus reducing fresh water requirements to 60 L/d. At the low and high truck system rates the present value of these benefits would be \$7300 (\$1200/a) and \$15000 (\$2400/a), respectively. These benefits are unrealistically high because some water conservation fixtures would certainly be utilized. If a European 3 L toilet, front load laundry and low flow shower head were installed the normal total consumption would be reduced by approximately 60% to 155 L/d. With the use of these fixtures, the benefits of greywater reuse would be \$2200 (\$360/a) and \$4500 (\$730/a), respectively, at the low and high rates. There are no existing package treatment systems available for this specific application but the benefits are quite high and it is possible that innovation or new technology could produce the necessary 100 L/d treatment system that would be economical. Naturally the economics and practicality are increased for multi-family buildings.

If rather severe water conservation fixtures, recirculating toilet, front load laundry and a hand-held or air assisted shower were used, the total water demand for a household of four would be reduced by 72% to 105 L/d and the maximum benefits of reuse would be reduced to \$1030 (\$167/a) and \$2070 (\$337/a), respectively, at the low and high rates. These values are quite low and even without a detailed assessment it is unlikely that an installed treatment/reuse package system could be produced for these amounts.

Therefore, moderate water conservation in conjunction with a greywater reuse system could provide a least-cost alternative if the necessary simple treatment technology were developed. However, the use of severe water conservation devices can reduce the household water demand to the point where reuse will be economically unattractive.

G.5.5 Total Reuse. For a household of four persons presently on a truck system, the benefits of total reuse can be estimated based on the expected normal consumption of 380 L/d of which 27% is hot water demand. At a water cost of \$10/1000 L and electricity cost of \$0.05/kW·h, the annual benefits would be \$1385 for water and \$33. for energy which is equivalent to a total present value of \$8700. At the higher rates of \$20/1000 L and \$0.02/kW·h, the present value of the possible benefits are \$17,800.

These high benefits are somewhat misleading since the 95 L/person·d could easily be reduced through the use of water conservation fixtures. For example, if a 3 L toilet, front load laundry, low flow shower head for all bathing and aerated faucets were used, the total water demand would be approximately 155 L/household·d or 39 L/person·d of which 14 L is hot water. The present value of the benefits of reuse would then be reduced to \$3350 and \$6900 at the low and high rates, respectively, and the installed incremental cost of these water conservation items would be approximately \$290 for a new installation and \$1125 for a retrofit. A more stringent strategy with a recirculating, front load laundry and miscellaneous other devices could reduce water use to 90 L/d or 23 L/person·d of which 9 L is hot. The benefits are thus reduced to \$2100 and \$4300 at the low and high rates respectively and the installed incremental cost of these water conservation items would be approximately \$670 for a new installation and \$1450 for a retrofit.

From these estimates, it can be seen that for a household reuse system to be economical it must have a present value of less than approximately \$2800 and \$5000, respectively, at the low and high rates. If half of the total cost is for annual O&M requirements, then the equivalent outlays are \$1400 in capital and \$230/a in O&M at the low rate and \$2500 in capital and \$410/a in O&M at the high rate. Considering the complexity of a system with reuse for drinking requirements, it does not appear realistic to expect technology at or below these costs. For a multifamily building, the benefits are higher but so are the costs and without doing any detailed calculations, total reuse still does not appear to be attractive. Again, the other benefits such as autonomy and zero pollution may make reuse more attractive at particular locations.

APPENDIX H

COMMUNITY SYSTEMS

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H. COMMUNITY SYSTEMS

Water demand for individual houses and buildings as well as for the overall community are dependent upon the type of utility system and its design as well as the plumbing within the buildings. For example, houses served by truck systems typically have 40% to 60% of the demand of a house on a conventional piped system. There are also variations of piped systems which can significantly influence the demand.

H.1 Piped Water Systems

Water demand and wastewater flows in piped systems can be reduced by a number of measures but the degree of reduction is very dependent on the characteristics of the existing system. One method is to keep the water main operating pressures at a minimum since high pressures result in wasting of water at uncontrolled faucets, for lawn watering and other uses and from leaks. The water main pressures could be increased only when high flow rates are necessary for fire flows. Pressures within elevated areas of the community or high buildings could be increased individually rather than maintaining a high pressure within the whole system. In other situations, it may be better to install pressure regulators within individual buildings where the main pressure is excessive. This proved very successful in the Washington appliance test program (WSSC, 1973). Original pressures of 480 to 825 kPa were reduced to 350 kPa and water demand was reduced by 16% to 24%.

Another approach is to limit the flow rate in the supply line to each building by the installation of an inexpensive constant flow device. Therefore, only one or two faucets could be opened at once but pressure would be maintained. A 9 L/min flow control valve installed in household supply lines in Kitwe, Zambia reduced water use by 25% to 30% and no complaints regarding inadequate supply were received (McJunkin and Marais, 1966).

Losses from water systems through breaks are often significant but are sometimes difficult to detect, locate, and rectify. A water balance on the system with actual or estimated demands may indicate excessive losses which can be systematically tracked down. Where bleeders are used to maintain a flow to prevent freezing, technical and administrative methods to control or eliminate these should be investigated. Other high demands such as from the wasting of excessively warmed water in the system should be investigated to eliminate the cause.

The Environmental Protection Agency (1974) has emphasized the reduction in wastewater flows through the elimination or control of infiltration. This is more significant in older systems that may have breaks in the sewer lines and those that have been designed with non-watertight joints or appurtenances. The benefits of an infiltration survey and repairs will be site-specific depending on the condition of the lines and the groundwater table. New systems should utilize pressure rated pipe and joints.

H.1.1 Buffer Tanks in Buildings. To reduce the peak demand and therefore the size of the water mains, small storage tanks and pressure pumps could be installed within each building. These could be continuously refilled very slowly as demand lowers the reservoir. Alternatively, the tank could be intermittently refilled every two to seven days, and the mains drained when not operating (James and Suk, 1977). With such a system, water is obtained indirectly from the water mains and there is a somewhat limited volume available. Therefore it would be expected that user habits would be influenced such that water demand would be somewhere between that expected on a fully trucked system and a conventional piped system.

H.1.2 Piped Water Only. In some cases it is cost-effective to distribute water by a pipe system but to collect wastewater by pumpout. Generally, such a system is more applicable if only small diameter water mains are used, perhaps with buffer tanks in the buildings. They can be designed to operate during the summer only. Such a system services houses on Latham Island in Yellowknife, N.W.T. that normally have a trucked water and sewage system. During the summer when piped water is available, the volume of sewage that is pumped out increases by approximately 15% to 20%; however, water demand increases more than this, primarily for outdoor uses such as lawn watering.

H.2 Non-Gravity Piped Sewer Systems

Pressure and vacuum sewer systems do not require the large volumes of water that is necessary to transport wastewater in gravity sewer collection systems. Vacuum systems move wastewater in slugs to a central collection tank using air being sucked into the system as the driving force. A special toilet that uses only 1.5 L of water can be used and greywater is admitted through a special valve. Relatively small diameter pressure rated pipes are used and there is no infiltration. With low pressure sewer systems, household wastewater is collected in a small holding tank and is periodically pumped into the small diameter collection main. Because the distance to the holding tank is short, a low water use toilet such as the European 3 L toilet could be used.

Therefore, with either system, water use for toilets can be drastically reduced and of course other water conservation devices can be used. However, given the same fixtures, the water demand will always be higher than that used by a trucked system since with piped systems there is no danger of running out of water or overflowing holding tanks. If there is a limited quantity of water available, a truck system is probably necessary to control demand. In other cases, the reduction in water demand possible with pressure and vacuum collection systems may enhance their economics to the point where this along with their other advantages make them more economical than a conventional gravity sewer system. Both pressure and vacuum systems have been used in Alaska (Rogness and Ryan, 1977; Ryan and Rogness, 1977).

H.3 Central Facilities

The installation of central facilities which may include laundry, showers and toilets is particularly applicable for camps (Given and Chambers, 1976) and to improve the level of services available in communities with no utility infrastructure and where the existing houses have little or no plumbing (Puchtler et al, 1976).

Because of the high water use at such a central facility, it will be economical to incorporate various water conservation measures.

When water is limited, such as where the complete winter's supply must be stored, and/or where the unit cost of water and sewage service is high, such as for truck systems, reuse should be considered to reduce demand and costs. In some cases, the possibility for conservation and reuse may even dictate the use of a central facility.

The benefits of a central facility are the reduction in the individual building plumbing, appliances and household water demand. Because of the low household demand it is unlikely that a piped system would be economical, therefore a truck and/or individual haul system would be used. The economics and practicality of operating a central facility are enhanced when there is a high usage and perhaps where it is incorporated into a large hotel, hospital, shcool, residence or a multi-use complex. This is particularly true where reuse is considered due to the operating requirements of the treatment system. The benefits of reuse at a central facility are the reduction in pollution and water and sewer service requirements of the treatment system. The benefits of reuse at a central facility are the reduction in pollution and water and sewer service requirements. They will be site-specific depending on the facilities, the usage and the unit costs. For example, if the residential laundry and bathing functions were transferred to a central facility with reuse, the present value of the benefit at the rate of $10/1000 L is $400/person ($66/person.a) and when the rate is $20/1000 L the benefit is $800/person ($132/person.a).

APPENDIX I

CONSUMER EDUCATION

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I. CONSUMER EDUCATION

Many devices are available to conserve water, reduce wasteflow, and save energy in the home. Most of these devices are inexpensive and relatively easy to install; however, without consumer education and acceptance on the "value" of these devices few will ever make it off the shelf. It was expressed by Maurer (1975) that a great need exists for public information and education on the benefits and necessity for water conservation and on the availability and characteristics of water saving devices. Cole (1975) felt that all incentives to citizens to save water and money need to be examined, and understood well in advance of a successful program to change people's habits and life styles, and to persuade them that the total direct and indirect costs of resource waste are too great. To help generate and sustain a high level of citizen concern and participation, a sustained youth and adult education program is vital, including attention to a regular public information program.

The Washington Suburban Sanitary Commission's (WSSC) study between 1972 and 1973 is an example of the effectiveness of a public education effort. To reduce the volume of sewage flow to the overloaded treatment facility in the Cabin John, Maryland area of the United States, the WSSC developed publicity material to encourage voluntary customer participation in modifying household water use habits. The significance of citizen participation for conservation was clearly specified from the beginning of the project. Pamphlets filled with water-saving suggestions were distributed to large apartment complexes, townhouses and private homes. Toilet inserts, reduced flow shower devices and pressure-reducing valves were installed in many of the same dwellings. A series of speaker, slide and movie presentations gave precise information to community and school organizations on household water conservation. Promotional activities in the form of customer contests were organized with prizes of U.S. Savings Bonds awarded for new water-saving ideas. As a result, the reduction in water consumption ranged from 12% for apartments to 20% for single family houses. The WSSC felt that the resultant reductions in water use were made possible through the water-saving installations coupled with the extensive public education and publicity campaign. Attitudes were thus manipulated, and the results were a desired behavioral change resulting in reduced water consumption.

A more extreme example are the drought management practices instituted in Marin County, California to deal with their two year long water shortage. In 1976, media coverage and direct public communication of the problem and necessity to ration enabled the Marin Municipal Water District to successfully implement rationing involving cuts of 25% to 30% of average annual demand. To reduce water consumption to a further 57% in 1977, county water officials gave each customer an allotment of water, based on the number of people in the household. To maintain the quotas implemented, stiff new water rates were imposed. The basic rate was doubled, anyone who used up to twice the quota paid more than eight times the old rate, and usage beyond that cost 40 times the pre-drought rate. To help their customers meet these quotes, the district distributed water saving tips and other instructions plus offered free water saving kits, which included low-flow shower inserts and bottles to put into toilet tanks. They also instituted and maintained a weekly consumer reporting system using local newspapers. As a result, Marin County residents reduced their water consumption by 65%. When the drought ended and restrictions were relaxed according to Consumer Reports (May, 1978), water consumption was still running 45% below pre-drought levels.

While these two examples differ in their severity and reasons for initiating a water conservation program, both point out the need for consumer education, and most importantly consumer acceptance of any water conservation measures or practices. Attitude and behavior changes should be the first step and continuing priority in a water conservation program. Milne (1976) stated that a family education program teaching new "tricks" about consumption behavior patterns brings about subtle changes in everyone's attitude. The way each individual uses water is strongly influenced by the groups attitudes about water consumption. Generally, the North American attitude towards water use has been influenced by a seemingly unlimited supply of water at nominal cost, which will be difficult to change.

To overcome these phychological factors, one strategy used in the WSSC (1972) and Marin County (Nelson, 1977) programs was to place emphasis on household water saving facts and tips. Many of the ideas and suggestions that were made available had been submitted by the citizens in response to public education compaigns. Milne (1976), incorporated many of these ideas into four scenarios representing the complete range of options available to the homeowner, beginning with the simplest and ranging through the most complex (least expensive to the most expensive). Following, listed under the main household water using events, are the options involving little or no expense to the homeowner. Suggestions on how to curb outdoor usage have also been included, although many of these may not be applicable in much of the north, particularly where there are no lawns.

It should be noted that these suggestions only constitute a small portion of an educational campaign. The goal under the total approach is to achieve water conservation by educating and making the consumer conscious of the value of the water and related energy resources and why each individual should practice wise use of each. Economic and environmental benefits are usually stressed and all forms of media are used to get the message across. The consumer is also provided with information on the availability and ratings of various water saving devices, and the dollar savings to the homeowner are emphasized. If the consumer does not have a reason or incentive to save, many suggestions will fall on deaf ears and distribution of brochures and mailers will end up in the household trash can. However, the consumer must also know how to save and if the following suggestions are put to use they can be used year in and year out; they just make good water conservation "cents".

I.1 Toilets

- Place a waste paper basket and ashtray in the bathroom and do not use the toilet simply to flush away facial tissues, cigarette butts or other similar wastes. Toilets use about half of a family's indoor water consumption or about 400 litres per day.

- It may not be necessary to flush after every urination, unless there are health or aesthetic reasons.
- A great weakness of the water closet is that when it gets out of adjustment and is not properly cared for, it can leak and, quite often, it leaks silently. Regularly test for toilet tank leaks by putting a few drops of food colouring in the tank, waiting a few minutes or overnight and check for colour in the bowl. If either the flapper valve or ball cock is defective, replace it with a leak proof or leak signaling type.
- If the water level in the tank is not at least 1.5 cm below the top of the overflow tube, bend the float rod to lower the water level, but avoid any adjustments that will cause any need for a second flush.
- Experiment with toilet inserts to reduce flush capacity to about 11.4 to 15.0 litres. Try a couple of water-filled plastic jugs of the type used for milk or cleaning products or one of the inexpensive manufactured inserts. Avoid bricks, because they can crack the tank and will disintegrate into the water.

I.2 Bathing and Personal Hygiene

- Examine the family's attitudes about bathing (functional, symbolic, habit, etc.). Think about the way each different person bathes, how much water each member of the family uses, and how each could save.
- When preparing a shower or bath, run only the hot water at first, thus water from the cold feed will not be wasted while waiting for the hot feed to warm up.
- Unless you can shower in less than 6 minutes or have a low flow shower head, a bathtub will use less water.
- When drawing a bath, close the drain in the tub before turning on the water, the water will soon be hot and the temperature can be mixed later as the tub fills.
- Filling the tub only 1/4th of the way is usually sufficient to cover one's body.

- Don't let children fill their own tub until they understand that when they get in, the water level rises.
- Sharing the tub water is done in many families, and is even more common in other cultures.
- Make sure you know the capacity of the water heater; considerable water can be lost trying to get hot water out of a cold tank.
- Teenagers have a mysterious propensity for long showers, their duration seems to be limited only by the amount of hot water available (a wind-up kitchen timer is a useful bathroom accessory).
- Limit everyone's time in the shower; bathing is the second largest water consumer; a 5 minute shower can use 50 to 200 litres of water; time your next shower.
- Soaping up with the shower off will save about 19 to 40 litres in every shower.
- Turning the water off when brushing teeth could save 19 to 40 litres of water per day.
- For hand razor shaves, use a filled sink rather than running water.
- It takes less energy to run an electric razor than to heat water for shaving, and so the water savings are a bonus.
- When shampooing your hair try to turn off the water when it is not needed.
- Eliminate all faucet drips by replacing any defective faucet washers. One drip per second sends 27 litres per day or 10,000 litres per year down the drain. If this is hot water, it took about 600 kW·h to heat that water, about the same as leaving a light bulb on all year. A 1 mm stream will waste 110 litres in 24 hours or 40,000 litres per year.
- Install a flow control insert in all shower heads that use more than 12 litres per minute.
- Install aerators on all faucets not so equipped, especially if they are used frequently, or if they control hot water.

- Replace worn out faucets with washerless faucets, spray taps, self-closing mixing valves, pressure-balancing mixing valve, or thermostatic mixing valve.
- Replace malfunctioning shower heads with low-flow models.

I.3 Laundry

- Examine the family's attitude about clothes; how often they are used, how they are kept clean, and when they are to be washed.
- If hand washing clothes, do not use running water; wash them in batches of similar colors and in sequences of increasingly dirtier items, so that the same wash water can be used over and over.
- Washwater from machine or hand wash can be reused to pre-soak dirty sneakers, or other hard-to-clean items.
- Automatic washing machines use between 120 to 260 litres per full cycle, so make every load count.
- If the washer is equipped with a water level setting control, which will permit partial filling of the tub if less than a full load is to be washed, know the capacity for each water level setting and amount of decreased detergent.
- If the washer permits variable temperature selection; save energy and rinse in cold water as often as possible, if not for every wash load.
- When washing clothes, use the suds saver when available; it will save 60 to 70 litres per load (plus detergent and energy).
- Replace defective washing machine with a water saving model. Front load models average as little as 120 litres per full cycle, and models with the "suds-saver" type option save almost half the water, both in addition to detergent and energy.

I.4 Kitchen, Dishwashing, Drinking and Cooking

- When hand-washing dishes first soak them in a filled sink with detergent and then be extremely stingy with the rinse water; washing a stack of dishes and rinsing them all at once saves time, water, and energy.

- When washing dishes by hand use scrubbers, sponges and any other labor saving convenience devices that will make cleaning faster and reduce the need to add more water.
- If you use your automatic dishwasher efficiently, it probably saves more water in the long run, unless you are a very frugal hand washer.
- Learn the correct amount of detergent required for dishes, never use too much; extra detergent may mean extra rinsing.
- Use low sudsing detergents; they require less rinse water (contrary to popular belief, foam has no effect on cleaning performance).
- Don't use the extra long pre-wash and scrub cycles on your dishwasher unless absolutely necessary; if you experiment with shorter cycles and less detergent, you will be surprised to find dishes come out just as clean.
- If a variable load control is available on your dishwasher use it whenever appropriate; it was designed to save you water (and energy).
- Don't waste water rinsing dishes before putting them in the dishwasher, just scrape off the scraps; your dishwasher is designed to clean even very dirty dishes.
- If the dishwasher is not getting dishes clean, check for clogged pumps, sticking rotors, leaking hoses, etc.
- When filling a kettle, see how close you can come to estimating the exact amount needed. Unused heated water wastes energy and this extra water is often poured down the drain, wasting both the energy and the water.
- When cleaning vegetables, use a filled sink and a vegetable brush, and wash all the meal's vegetables at once.
- When peeling vegetables, it is probable that you don't need water running.
- Use only the minimum water to cook foods; otherwise flavor and food value may be wasted along with water.

- Consider other methods of cooking which may use less water (and energy), such as pressure cookers, broilers, a wok or steamers.
- Always use a lid on pots.
- The water used to cook vegetables can be "re-cycled" in soups to add flavor and nutrients.
- Thaw frozen foods ahead of time; don't use water to quick-thaw foods.
- If you remove the ice cube tray from the freezer a few minutes ahead of time, you will not need to use running water to release the ice cubes.
- Don't make more coffee, tea, or food than will be consumed.
- Keep a bottle or two of water in the refrigerator so water needn't be run from the sink to get a cool drink.
- Do not use garbage disposals except at the end of cooking or clean-up periods or when full.
- Don't use garbage disposals for items just as well thrown in the garbage can, such as orange peels, chicken bones, and other items requiring much grinding time and water.
- Replace malfunctioning dishwasher with a water saving model (some machines use as little as 45 litres per full cycle) and be sure it has partial wash cycles.
- Carefully consider a bottled water or other type of chilled water dispenser; it will save water but may use more energy in the long run.

I.5 Plumbing and Sewage System

- Conduct a leak check. At a time when there is no water use inside the house, check the water meter, wait as long as possible then check it again; any change in the reading indicates that you have a leak.
- Check the water pressure indoors; it if exceeds 345 kPa have the water company adjust your pressure reducing valve, but if it is

below 100 to 140 kPa, toilet tank valves may malfunction. Lowering the pressure means lower flow rates and is one of the easiest ways to reduce overall consumption.

- When on vacation, turn off the house water; a leak while you are away could do a lot of damage.

I.6 Outdoors

- Water the lawn in the early morning; this avoids evaporation losses.
- The key to successful lawn irrigation is to irrigate slowly, deeply, and infrequently.
- Do not allow irrigation water to flow into a gutter; that is literally throwing money down the drain.
- During the hot summer months, raise the blade on the lawn mower to about 4 centimeters in height. This provides shade for the roots and helps reduce water loss.
- Sweep sidewalks and driveways and rake lawns instead of washing them down with the hose.
- Use pistol-grip nozzles (spring shut-off) on all hoses to avoid waste, and always turn off the faucet when through to prevent leakage.
- Mulch planted areas heavily (especially when planting new turf) for improved absorption and reduced evaporation.
- Figure out how much water is being used outdoors by comparing water bills for summer and winter. Hoses of varying diameter at normal home water pressure will deliver anywhere between 2275 and 7200 litres per hour.
- When watering, remember that drought-tolerant plants can be water-wasters; they have the capacity to take up a great deal of water in a short period of time.
- Keep a record of frequency of watering and amount of water used, to establish the best watering schedule.

- "Aerate" the lawn regularly to increase its ability to absorb moisture to root level.
- Dig basins around the "drip line" of trees and shrubs, it not only saves water but is better for your plants.
- Flooding and soaking is the best way to water shrubs and trees.
- Use an alarm clock or the stove timer to remind you to shut off the sprinklers.
- Hand watering of lawns and gardens is more efficient and reduces waste.
- Keep sprinkler heads clean to prevent uneven watering, and make sure they are located correctly to cover the greenery and not the paved areas.
- Avoid sprinklers that produce a fine mist; too much water is lost in wind and evaporation.
- Don't leave sprinklers on unattended.
- Consider using an instantaneous moisture indicator or other soil moisture measuring technique to evaluate the effectiveness of garden irrigation.
- Install an automatic shut-off on all sprinkler hoses and begin to keep a record of the frequency of watering and the quantity consumed.
- Consider installing an electronically controlled automatic sprinkler system.
- When re-planting ground cover or sections of the garden, use native or indigenous plant species that survive on rainfall alone (if this is impossible, at least collect water-loving exotics into areas that can be easily watered separately from the rest of the garden).
- Make major landscape changes and new plantings just before the rainy season.
- Re-work topography of landscaped areas to prevent run-off.

- Spend less time washing the car; a 20 minute car wash can use between 760 and 2275 litres.
- When washing the car, rinse it once, then use a bucket of soapy water to wash it, and then one more quick rinse; you might think about taking it to a car wash instead because virtually all of them recycle their water.

APPENDIX J

SELECTED ANNOTATED BIBLIOGRAPHY

BAILEY, J.R., R.J. BENOIT, J.L. DODSON, J.M. ROBB and H. WALLMAN. 1969.

"A study of flow reduction and treatment of wastewater from households," Water Pollution Control Research Series, Environmental Protection Agency, Washington, D.C., 152 p. Also: FWQA Contract Project 14-12-428, U.S. Government Printing Office, Washington, D.C. Also: Water Pollution Control Research Series, 11050FKE, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio, 154 p.

ABSTRACT

This study, one of the first and most often referenced, identifies practical means of household water conservation and waste flow reduction. The possibility of household waste treatment and on-site re-use are analyzed. Commercially available devices for water saving are described along with a literature review on advanced water and waste treatment. A consumer survey showed little unfavorable reaction to flow reduction devices except the home urinal and possibly the recycle toilet. It was also shown that water used for bathing and toilet flushing can be substantially reduced through the use of more efficient appliances and plumbing devices.

CHAN, M.L., J. EDWARDS, M. ROBERTS, R. STEDINGER and L. WILSON. 1976.

"Household water conservation and wastewater flow reduction," Office of Water Planning and Standards, U.S. Environmental Protection Agency, Washington, D.C., Contract No. 68-02-2964, U.S. Department of Commerce, National Technical Information service, Publication No. PB-265578, 143 p.

ABSTRACT

This report studies the legal and economic aspects of devices and policies to reduce water and wastewater flows. After reviewing the literature, the report considers building and plumbing codes from selected areas to see whether or not they provide constraints on the introduction of water-saving devices; and considers state laws to see whether they permit pricing schemes which encourage conservation. A computer model was developed, using water demand functions and cost functions from the literature, to determine the benefits to consumers and producers of various pricing systems. Through use of a second computer model, benefits are calculated for various replacement strategies in the adoption of water-saving devices.

COHEN, S. and H. WALLMAN. 1974.

"Demonstration of waste flow reduction from households," Environmental Protection Agency, Cincinnati, Ohio, Environmental Protection Technology Series, EPA-670/2-74-071, 111 p.

ABSTRACT

A two year demonstration program was conducted to evaluate water savings, costs, performance and acceptability of various water-saving devices. Water requirements for toilet flushing were substantially reduced in an economically attractive and aesthetically acceptable manner. Shallow trap and dual-flush toilets resulted in average decreases in toilet water usage of 25% and 23%, respectively. Flow restricting shower heads proved to be relatively ineffective; however, this result may have been due to use patterns unique to this study.

Wash water treatment and recycle for toilet flushing provided satisfactory operation through the test period. The average savings with toilet flushing reuse ranged between 23% and 26% of total water usage. For single-family dwellings, recycle systems could effect marginal cost savings in high water use rate areas. They are definitely warranted when septic systems with poor drainage (due to soil or topography) are encountered.

GRIMA, A.P. 1972.

"Residential water demand; Alternative choices for management," University of Toronto, Department of Geography, Research Publications, University of Toronto Press, 211 p.

ABSTRACT

This study focuses on the identification of variables that affect the level of residential water use and the level of the related investment in water supply. The factors affecting residential water use may be conveniently classified into three groups: those that vary from region to region; those that differ from one water utility to another; and those that vary from household to household.

Inter-regional differences in residential water use arising from cultural considerations are outside the scope of the study. The study area, cities in south central Ontario, are assumed to be homogeneous in this respect. Supply considerations affect the quality, volume, and dependability of residential water but they do not affect the potential rate of use. Of the household characteristics that affect water use, only income and size of household are discussed. Density of housing is controlled for by limiting the discussion to single unit dwellings. The group factors that vary from water utility to another includes variables relating, among others, to quality of service. The quality of service is uniformly high in the study area and therefore these factors are excluded from the analysis. The main emphasis in the anlaysis is upon metering and pricing. Residential water demand is shown to be elastic with price, and therefore, water managers can use pricing policy to manipulate water demand to reduce overall costs.

LINAWEAVER, F.P. (Jr.), J.C. GEYER and J.B. WOLFF. 1966.

"Report V on phase two of the residential water use research project, final and summary report," Department of Environmental Engineering Science, The John Hopkins University, June 1966, Also published as "A study of residential water use," Federal Housing Administration, Department of Housing and Urban Development, Washington, D.C., February, 1967.

ABSTRACT

This report summarizes a massive study of water use patterns of 41 communities over a five year period and discusses some of the major factors that influence these patterns. The four factors discussed are economic level, climate, metered versus flat rate pricing, and a section on "other" functions. The report does not give much information on how water is used or can be conserved inside an individual residence. The authors do, however, propose some solutions, for example, a judicious means of metering; criteria by which to determine the level of drought risk for which a sprinkling system should be designed. The research project report includes a tremendous amount of well documented data and information on a good cross section of the United States.

MILNE, M. 1976.

"Residential water conservation," California Water Resources Centre Report No. 35, University of California/Davis, 469 p.

ABSTRACT

A brief history of how water has been used in the home is presented, along with a typical residential water consumption profile. The impact of the economic, institutional, sociocultural, and technological constraints are discussed with reference to the innovation and implementation of water conservation. Commercially available devices which affect water consumption in the home are evaluated with a recent search of patent applications discovering numerous new water-conserving fixtures. In an attempt to discover future trends, a survey was made of the relevent aerospace technology, including Apollo and Skylab systems, as well as the systems installed in commercial jet aircraft, trains, and ships. Four scenarios are laid out to show the homeowner different strategies for reducing water consumption, and a series of recommendations are made defining specific actions that can be taken by utility companies, homemakers, and plumbingware manufacturers to reduce residential water consumption. An Appendix contains a 250 item annotated bibliography and a directory of manufacturers.

ORR, R.C. and D.W. SMITH. 1977.

"A review of self-contained toilet systems with emphasis on recent developments," IN: Utilities Delivery in Arctic Regions, Edmonton, Alberta, March 16-18, 1976, D.W. Smith, ed., Environmental Protection Service Report No. EPS 3-WP-77-1, Ottawa, pp. 266-305.

ABSTRACT

The issues of safe water supply and sanitary human waste disposal have been a major concern of northern public health officials for many years. The incidence of communicable diseases in northern communities is generally as high or higher than anywhere else in North America. While the reasons for such a high communicable disease incidence are complex, most authorities cite the primitive methods of handling and disposing of human waste as a major causitive factor.

The objective of this paper is to review and evaluate self-contined toilet systems with respect to criteria which must be met for northern application. While some of these systems may be considered interim measures, pending the adoption of piped sewer and water systems, others may provide a viable long term method of handling human waste. The systems are divided into four categories: dry storage and removal systems; liquid borne storage and removal systems; liquid borne treatment systems; and dry treatment systems. A discussion of each category is given in the main body of the paper, with reference to specific toilet systems detailed in an Appendix.

RYBCZYNSKI, W. and A. ORTEGA. 1974.

"Stop the five gallon flush! A survey of alternative waste disposal systems," Minimum Cost Housing Group, School of Architecture, McGill University, Montreal, 82 p.

ABSTRACT

A survey of alternative domestic water conserving waste disposal systems is presented. The known methods for the disposal of household wastes are reviewed, noting the advantages and disadvantages, with special interest given to self-contained systems and those that use little or no water. A catalogue of data emphasizing how low cost waste disposal systems being manufactured in various countries is presented under the classifications of manual removal, mechanical removal, destruction, infiltration, and decomposition. A final summary chart gives concise data on all the toilets discussed.

SHARPE, W.E. and P.W. FLETCHER, eds. 1975.

"Conference on water conservation and sewage flow reduction with water-saving devices," Proceedings, April 8-10, 1975, Institute for Research on Land and Water Resources, The Pennsylvania State University, Pennsylvania, Information Report No. 74, 216 p, 20 papers.

ABSTRACT

Water use reduction with water-saving devices offers a major opportunity to alleviate some of the most pressing resource management problems. The proceedings are a current state-of-the-art assessment of water-saving device technology in the United States. The papers included, address themselves to the major questions associated with water-saving device development and use. Gaps in current knowledge are enumerated and the information necessary to fill these gaps is identified. The information contained will be of benefit to a broad spectrum of concerned individuals from the researcher to the facilities manager. A list of the individual authors and specific papers is included in the reference section.

WASHINGTON SUBURBAN SANITARY COMMISSION. 1973.

"Final and comprehensive report, Cabin John Drainage Basin water-saving customer education and appliance test program," Washington Suburban Sanitary Commission, Hyattsville, Maryland, 30 p.

ABSTRACT

The Washington Suburban Sanitary Commission reports on their pioneering effort designed to encourage voluntary customer participation in modifying household water use habits in the Cabin John, Maryland, Drainage Basin. Publicity materials filled with water-saving suggestions were distributed to large apartment complexes, townhouses and private homes. Approximately 4,800 appliances (toilet inserts, reduced flow shower devices and pressure-reducing valves) were installed in 2,400 of the same dwelling units. A series of speaker-slide presentations gave precise information to community and school organizations on household water conservation. As a result, the average savings in water consumption were 12 percent for apartments and 20 percent for single family houses. It was felt that the resultant reductions in water use were made possible through the water-saving installations coupled with the extensive publicity.

WASHINGTON SUBURBAN SANITARY COMMISSION. 1976.

"A customer handbook on water-saving and wastewater-reduction," The Washington Suburban Sanitary Commission, Hyattsville, Maryland, 21 p.

ABSTRACT

This booklet contains many water-saving ideas and suggestions in the interest of promoting the thoughtful use of one of the most important essential resources. Mention is also made of water saving devices which attach to existing fixtures as well as alternative fixture equipment. Water use figures are stated to point out actual quantities of normal use and waste.